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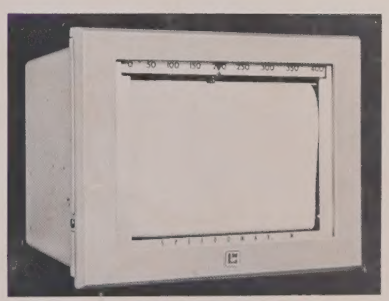
SPEEDOMAX® W MANUAL



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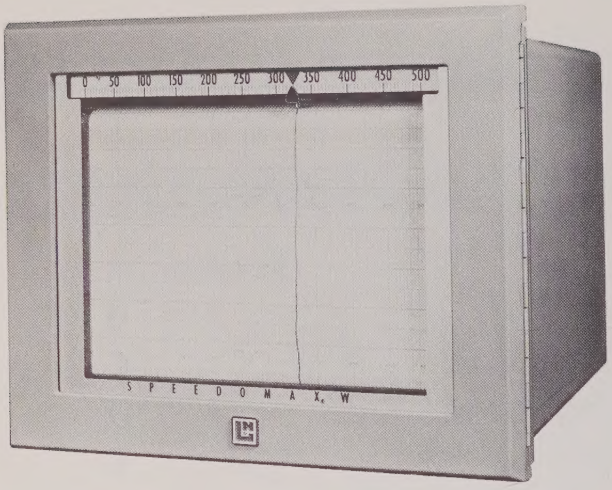
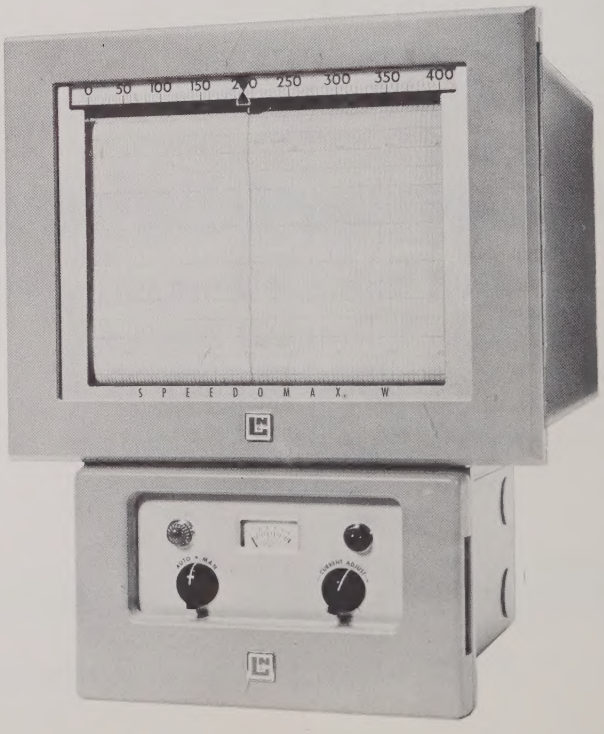


SPEEDOMAX W INSTRUMENT

SPEEDOMAX W INSTRUMENT WITH SERIES 60 CONTROL UNIT IN LOWER CASE



INTRODUCTION

USE OF THE MANUAL.....

This manual has been prepared to serve as both an instruction book for operation and maintenance, and as a source of general information on Speedomax W instruments. For ease in use, all information needed for placing the instrument in service, and for performing routine maintenance, is given in the first part of the manual. Servicing instructions given in Part II will, of course, be consulted as the need arises. Part III describes the basic characteristics of the instrument and, by contributing to an understanding of its capabilities and limitations, should aid in its proper application.

SCOPE.....

Cases—The Speedomax W instrument may be furnished by itself or with an auxiliary case. The auxiliary case usually contains control or other circuitry that works in conjunction with the instrument. Both types are illustrated on the facing page. Note, however, that only those components located in the case of the measuring instrument itself are considered here. For information on the lower case unit, the user is referred to other booklets supplied with the equipment.

Measuring Circuits—This manual covers those circuit types most frequently encountered. Where special arrangements are furnished, a supplementary sheet or booklet is supplied, if required. Where such special instructions conflict with this manual, they shall be considered authoritative.

IMPORTANT

When requesting information about this instrument, always furnish the instrument serial number. This number is marked on the nameplate inside the instrument case.

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INSTALLATION AND OPERATION I

Section A — INSTALLATION

UNPACKING

Remove the instrument from its packing case, and remove any shipping ties, clamps, or packing material. Any instructions given on the tags attached to the instrument should be carefully followed and such tags removed.

The instrument door can be opened by depressing the catch-release button, identified in Fig. A1. The shipping screw, also shown in this figure, must be removed before the instrument mechanism can be swung out. In swinging out the mechanism, use the handle at the lower right-hand corner, Fig. A1. The hinged casting stop, also identified in this figure, limits the mechanism swing to a safe distance.

MOUNTING

The Speedomax W instrument is arranged for flush mounting only. Figs. A2 and A3 give all necessary mounting dimensions. Note that Fig. A3 also applies when equipment other than a control unit is housed in the lower case of the instrument.

As noted in Figs. A2 and A3, the mounting studs supplied with the instrument are suitable for use with panels up to ¾" thick. When mounting the instrument on panels thicker than this, the longer studs required are to be supplied by the user.

The instrument case should be connected to a good earth ground unless specific exception is made on the instrument wiring diagram. The use of the ground (GRD) stud on the terminal board (see Fig. H4) will effect such grounding when the instrument is mounted on a metal panel that is properly grounded. Where an insulated panel is used, connection should be made from the ground (GRD) stud to an earth ground bus.

TEMPERATURE LIMITS

The instrument should not be installed in locations where the ambient temperature exceeds the range 16 F to 122 F (-9C to 50C).

WIRING CONNECTIONS

Detailed wiring connections are shown on one or more diagrams supplied with the equipment. Where a lower case unit is included, refer to the manual for that unit.

All wiring diagrams are self-explanatory. In making connections, however, the user is advised to observe the procedures and precautions which follow.

As indicated in Fig. A2, the cover plate can be removed to permit access to the instrument terminal board. All connections are usually made to the rear of this terminal board. If control or other auxiliary unit is used in the lower case, connections to the terminal board on the back of this case may also be required.

Connect power supply of the proper voltage and frequency as specified on the nameplate, located at the inner left side of the instrument case. In making the power connection, note the following:

(1) The power supply voltage must be within the limits 107 - 127v, a-c.

(2) The grounded side of the power line must be connected to the L_2 terminal of the terminal board. Use an isolating transformer if one is required, to permit grounding of the power supply.

(3) Power to all parts of the measuring instrument is supplied through a fuse and switch located on the amplifier chassis. However, this switch does not control the power to control elements. Therefore,

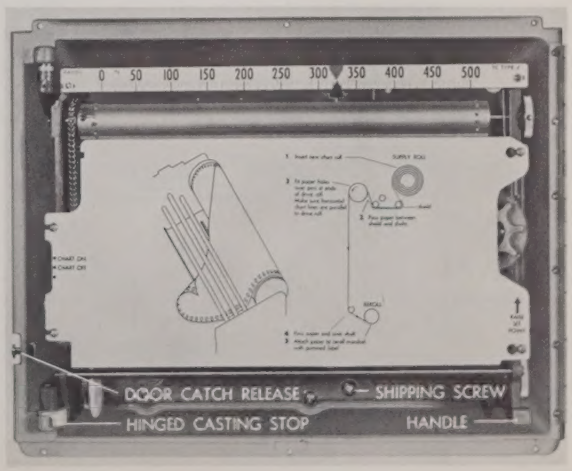
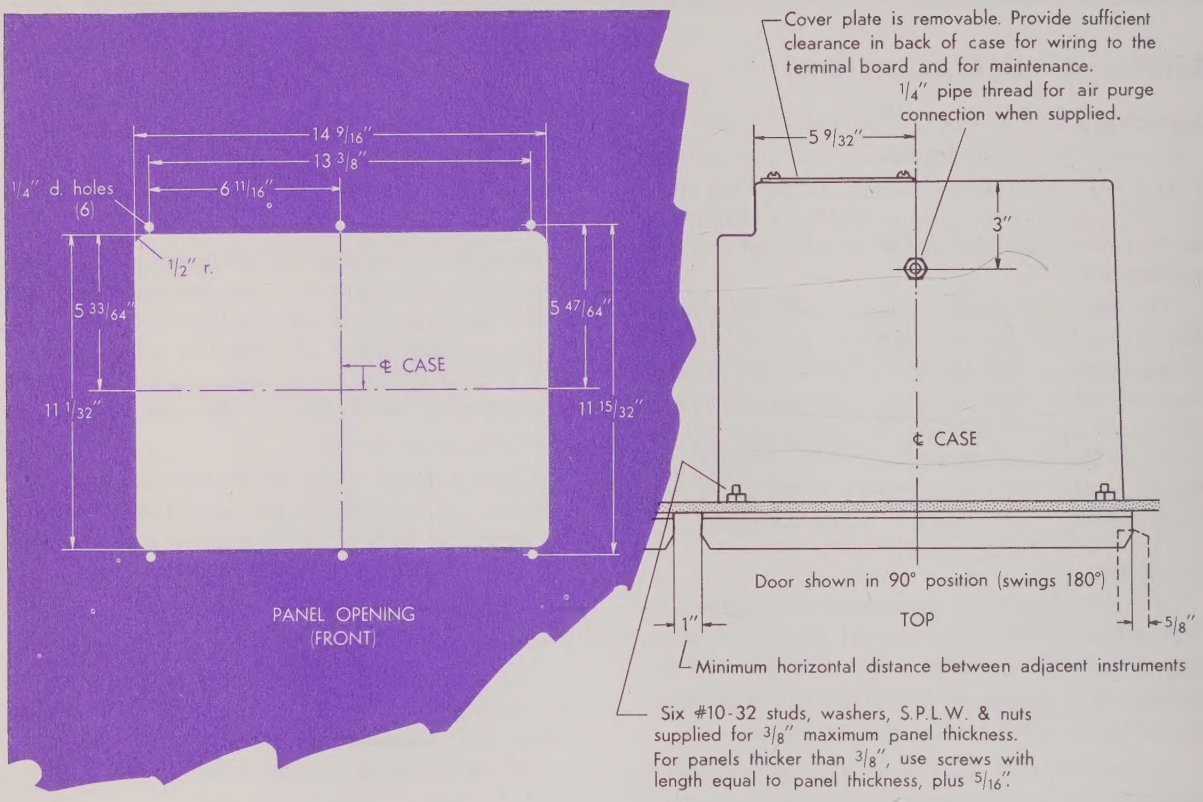


Fig. A1—Speedomax W, chart paper removed.


Cover plate is removable. Provide sufficient clearance in back of case for wiring to the terminal board and for maintenance.
1/4" pipe thread for air purge connection when supplied.
14 9/16"
13 3/8"
6 11/16"
1/4" d. holes (6)
1/2" r.
5 33/64"
5 47/64"
℄ CASE
11 1/32"
11 15/32"
PANEL OPENING (FRONT)
5 9/32"
3"
℄ CASE
Door shown in 90° position (swings 180°)
TOP
1"
5/8"
Minimum horizontal distance between adjacent instruments
Six #10-32 studs, washers, S.P.L.W. & nuts supplied for 3/8" maximum panel thickness.
For panels thicker than 3/8", use screws with length equal to panel thickness, plus 5/16".

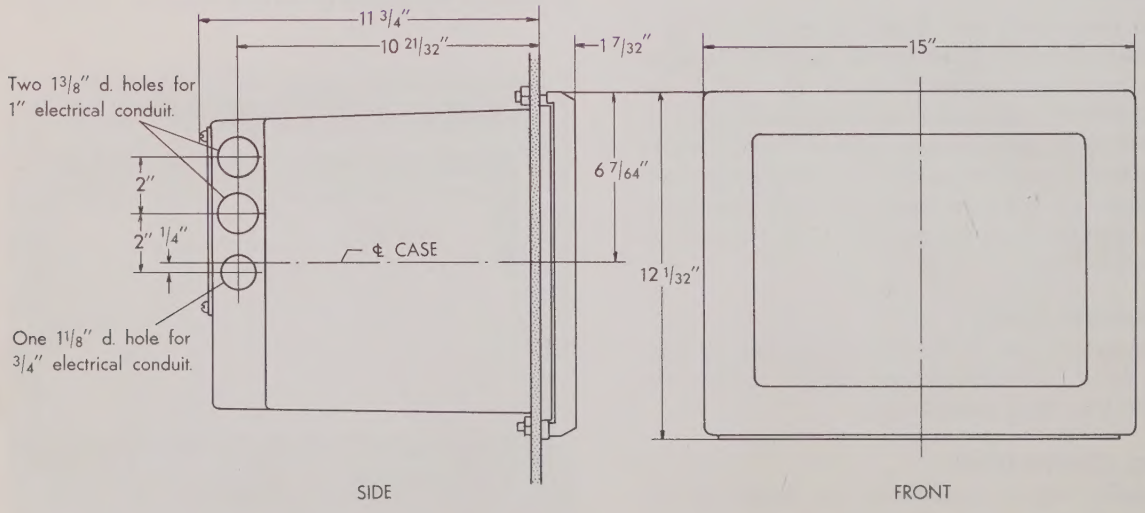


Fig. A2—Outline and mounting dimensions for Speedomax W.

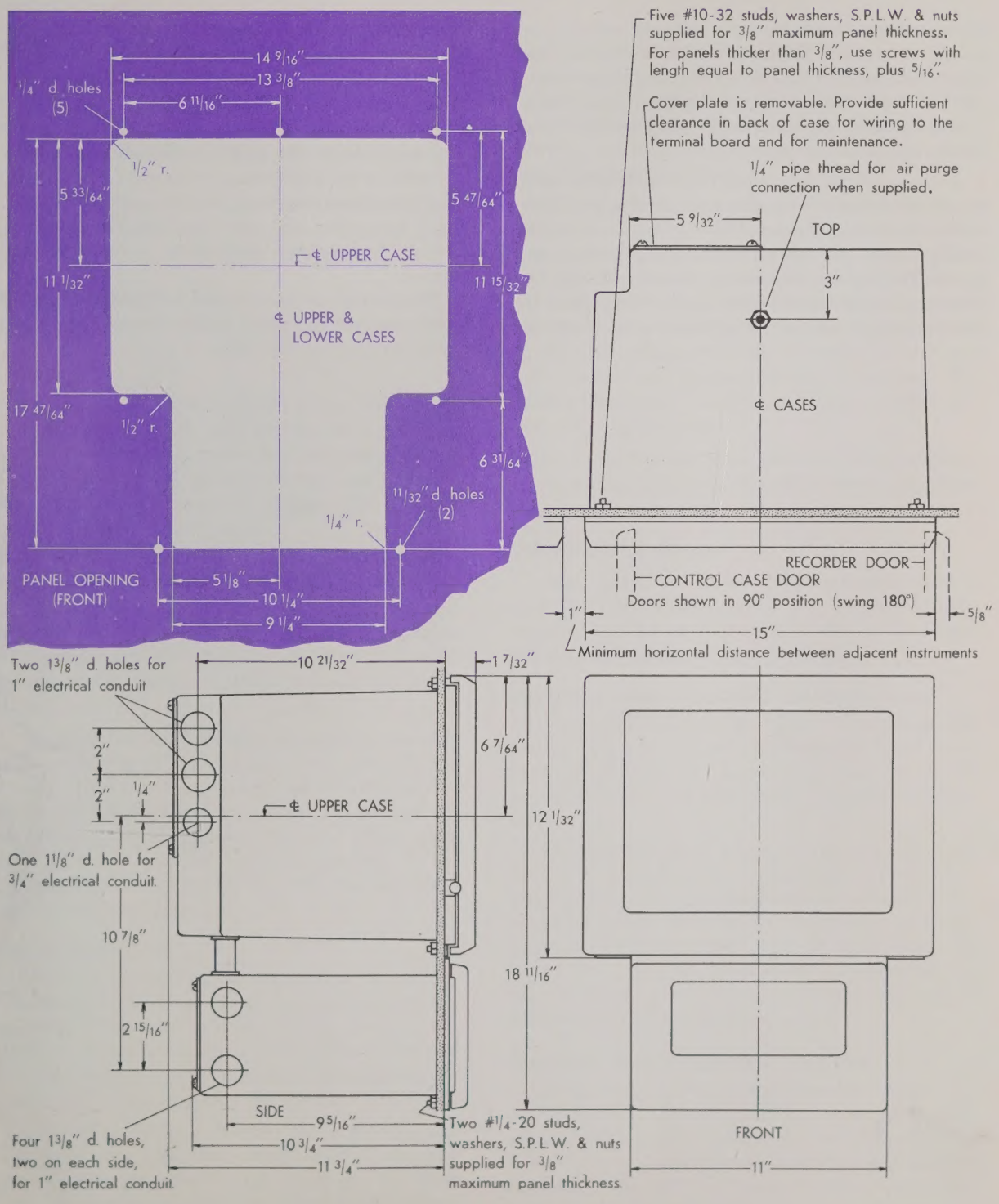


Fig. A3—Outline and mounting dimensions for Speedomax W with Series 60 case.

when control features are included, it is necessary to provide a separate fused switch in the power line external to the instrument. Allow enough fuse capacity for both measuring and control equipment. When a control unit is present, 3-ampere fusing is usually sufficient.

Connect the primary element, i. e., the resistance or voltage source being measured, to the terminals as shown on the diagram. Observe any instructions supplied with the primary element. Although no special precautions are usually required, it may be necessary in some installations to shield the primary element leads or to route them so as to avoid strong fields produced by transformers, electric welding equipment, induction heaters, etc.

Where the Speedomax W is used for measurement on high-voltage equipment, e. g., thermocouple temperature measurement of transformers, generators, etc., one side of the primary element should be grounded at the high-voltage equipment if the measuring circuit arrangement permits such grounding. This is to protect both personnel and instrument in case of high-voltage breakdown to the primary element.

The instrument case should be grounded unless specific exception is made on the wiring diagram.

PART 1—INSTALLATION AND OPERATION . . . . .

Section B—PREPARATION FOR OPERATION

CHART INSTALLATION

The number of the Leeds & Northrup chart to be used is marked on the nameplate inside the instrument case.

To install the chart, follow the steps illustrated in Fig. B1.

If the recorder is equipped with a chart tear-off device, chart installation will differ somewhat from that shown in Fig. B1. Refer to the appendix.

PEN PREPARATION

Important: In following these instructions, take care not to bend or otherwise damage the penpoint.

Filling — Loosen the clamp screw in the cover of the ink reservoir (see Fig. B2) to free the cover, and remove the reservoir from the carriage. Use the dropper to place ink in the reservoir and fill to ⅜″ from the top of the reservoir. Replace the reservoir and tighten the cover in place.

Priming — The recorder pen must be primed after the initial filling. That is, the pen capillary must be filled to start the ink flow. This process need be repeated only when the capillary is emptied during cleaning, or if it is allowed to run completely dry. For this reason, the pen should always be refilled before it is entirely empty.

To prime the pen, hold the pen capillary assembly as shown in Fig. B3. With ink in the dropper, fit the dropper spout over the penpoint and the other end of the capillary in the top of the ink bottle. Then squeeze the dropper until ink appears at the end of the capillary in the bottle. Remove the dropper and fit the capillary in place (see Fig. B2) with the end fitted through the hole in the cover.

PEN INSTALLATION

Hold the pen capillary assembly as shown in Fig. B2 and insert the lower end of the capillary into the top hole of the reservoir cover. Fit the pivots of the capillary assembly into the mating holes of the pen carriage. When properly mounted, the capillary assembly will swing freely on the pivots.

To remove the pen, reverse the procedure just described. Also note that, when desired, the pen reservoir and the reservoir top cover can be lifted from the instrument upon loosening of the clamp screw identified in Fig. B2.

SCALE, POINTER AND PEN LINEUP

All instruments are completely adjusted and tested before leaving the factory and should be in perfect operating condition when received. It is advisable however, to make the following simple check at the time of initial installation.

With the instrument turned off, remove the measuring slidewire cover and grasp the hub of the slidewire contact arm as shown in Fig. B4. Turn the arm to bring the pen downscale until the penpoint is on the first calibrated line of the chart. Under this condition the pointer should be on the first calibrated line of the scale. Then rotate the slidewire contact arm until the low end mechanical stop is reached. The pointer should now be on the dot below the first calibrated line on the scale.

If the instrument does not meet the foregoing requirements, the lineup should be corrected. Refer to Section H.

INSTRUMENT START-UP

After completion of the preparations as instructed to this point, the instrument may be placed in operation. Snap the on-off switch, located on the amplifier chassis, Fig. B5, to the ON position.

CHECKING AND ADJUSTING AMPLIFIER GAIN

The amplifier gain has been adjusted at the factory and will not ordinarily require initial readjustment. However, the instrument sensitivity should be observed and the gain setting corrected if necessary.

The optimum gain setting is that setting which gives maximum instrument sensitivity without causing "hunting", i. e., pen oscillation. If oversensitivity, characterized by hunting, or insensitivity is noted, turn the gain control knob, Fig. B5, to its clockwise limit. Then turn the knob slowly counterclockwise until the hunting disappears or shows as only a slight quiver of the balancing motor worm.

CHECKING AND ADJUSTING DAMPING

Instruments having a step response time of 1.0 second for full-scale changes of the measured variable are provided with a damping control rheostat. This is a screwdriver adjustment located on the range card mounting, Fig. B5. The proper setting should be determined after completing the circuitry from the measured variable source.

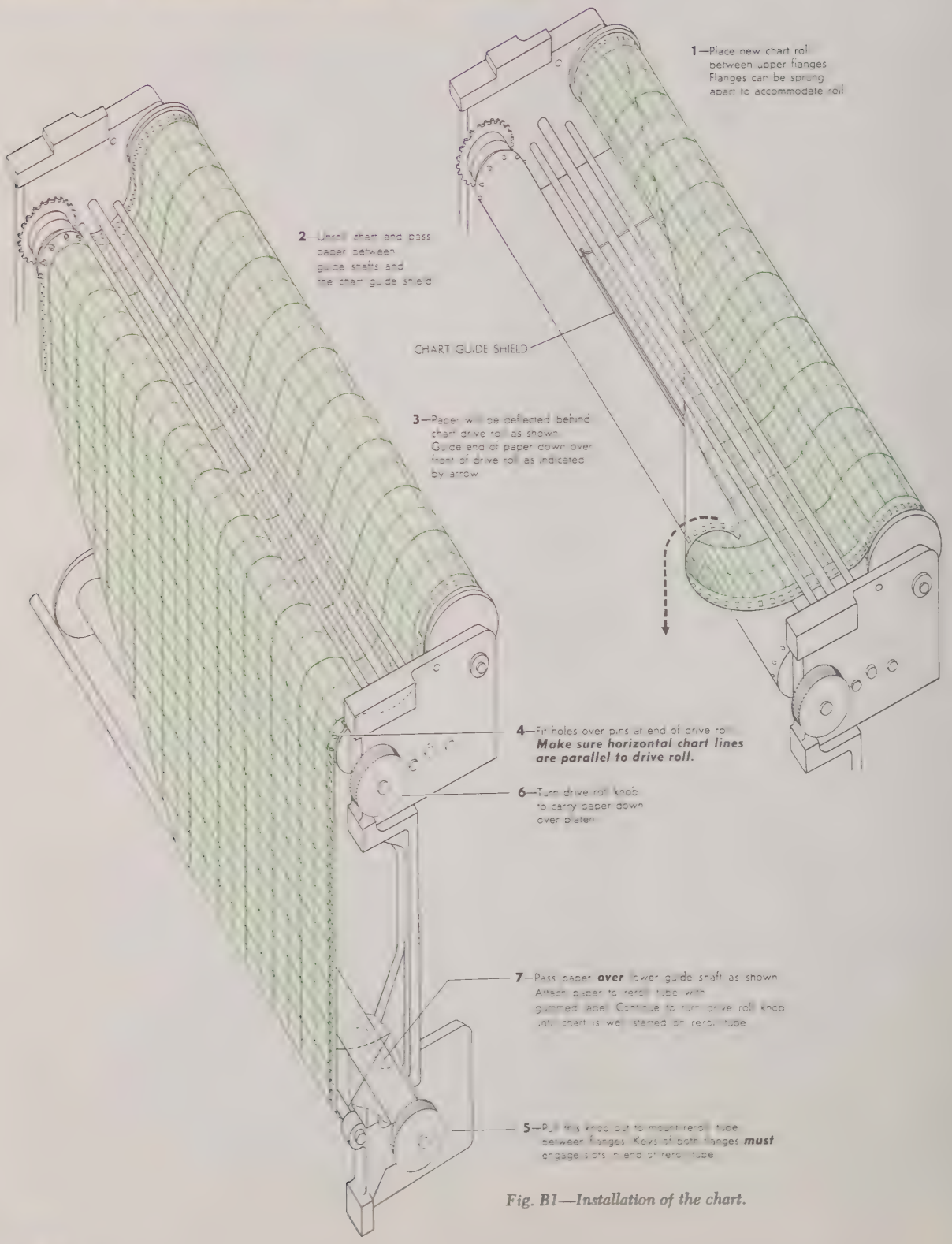

1—Place new chart roll between upper flanges. Flanges can be sprung apart to accommodate roll.
2—Unroll chart and pass paper between guide shafts and the chart guide shield.
CHART GUIDE SHIELD
3—Paper will be deflected behind chart drive roll as shown. Guide end of paper down over front of drive roll as indicated by arrow.
4—Fit holes over pins at end of drive roll. Make sure horizontal chart lines are parallel to drive roll.
6—Turn drive roll knob to carry paper down over platen.
7—Pass paper over lower guide shaft as shown. Attach paper to rear tube with gummed label. Continue to turn drive roll knob until chart is well started on rear tube.
5—Pull this knob out to mount rear tube between flanges. Keys at both flanges must engage slots at end of rear tube.

Fig. B1—Installation of the chart.

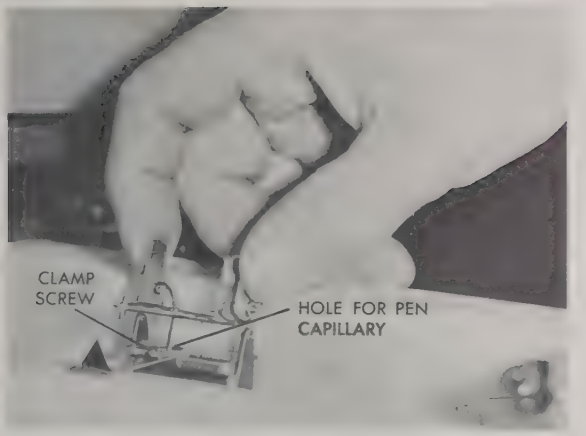


Fig. B2—Mounting the pen capillary assembly in the pen carriage. The instrument scale has been removed to show the parts.

Fig. B3—Priming the pen.

The optimum damping setting gives the smoothest and fastest balancing action. Manually rotate the slidewire contact arm to move the pointer several inches from the balance point. Release the contact arm and observe the pointer behavior as the instrument balances. Turn the damping adjustment counterclockwise until the pointer overshoots the balance point when this procedure is repeated. Then turn the adjustment clockwise until the overshoot just disappears.

ZERO OFFSET ADJUSTMENT

Certain instruments equipped with moderate impedance amplifiers (101120, 101121), in particular those with multiple spans, may show greater errors on lower millivolt spans than on the higher millivolt spans. This may be due to offset voltages generated in the input circuit of the amplifier. An adjustment is provided on the amplifier chasis (see Fig. B5) to reduce these internal offset voltages. This adjustment has been set at the factory and ordinarily will not require initial readjustment. However, after a certain period of use, readjustment may be found necessary. Refer to Section H. On fixed span instruments this offset can generally be compensated for by following the standard calibration procedures outlined in Section H.

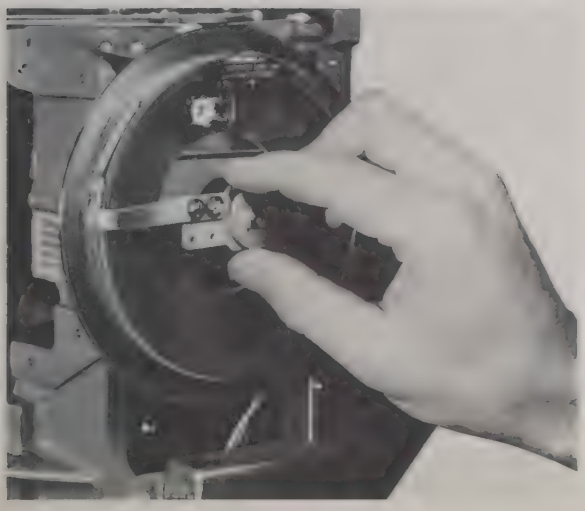


Fig. B4—Manual rotation of the slidewire shaft.

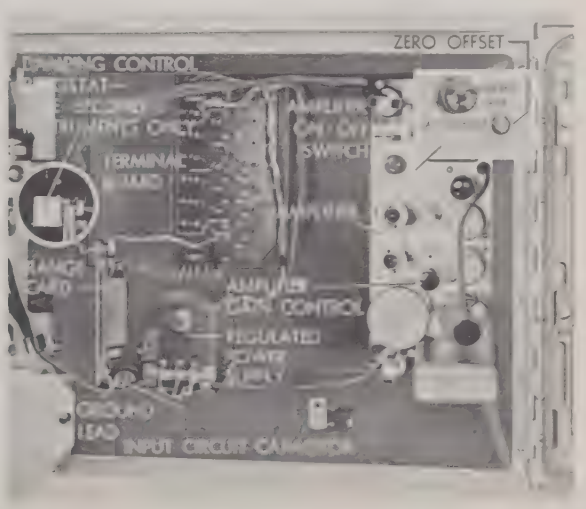


Fig. B5—Interior of case.

AMPLIFIER GROUNDING

Upon completion of the foregoing steps, performance of the instrument should be carefully observed. If sluggish operation, excessive dead band (see Section H), or erroneous readings are noted, the trouble may be caused by electrical interference entering the instrument amplifier. Quite often such interference can be readily eliminated by ungrounding the amplifier chassis and connecting it to the primary element circuit. In particular, this procedure is effective whenever interference is due to (a) instrument case and primary element at different ground potentials, or (b) primary element having an a-c or d-c potential with respect to ground. (For further discussion of interference, refer to section J.)

Note that the Speedomax W amplifier is provided with insulated mounting post and feet, so that its chassis is *not directly grounded* to the case. However, since most installations require a grounded amplifier, the chassis is connected to the case by means of a ground lead in the range card cable. See Fig. B5. This lead is grounded at the input circuit capacitor mounting screw. Thus if electrical interference is encountered, as evidenced by the symptoms described above, the chassis ground connection should be changed as follows:

(1) Unsolder the ground lead from the input circuit capacitor mounting screw.

(2) Solder the lead, just disconnected, to the center front lead of the input circuit capacitor. See Fig. B5.

Section C—OPERATING ADJUSTMENTS

Depending upon the type of measuring circuit employed, some instruments may require certain adjustments during normal operation. Such adjustments are properly made in accordance with the instructions of this section.

RHEOSTAT ADJUSTMENTS

Speedomax W instruments for use with some types of primary elements may incorporate one or more rheostats located at the rear interior of the case, above the range card. Such rheostats are to be adjusted by the user. Brief instructions concerning the adjustments are given below. When more detailed information is required, it will be found in the instructions furnished with the primary element.

RAYOTUBE INSTRUMENTS

The dial-operated rheostat at the rear of the instrument case is known as a Rayotube compensator. After installation of the equipment, this compensator should be adjusted to make the instrument reading agree with the temperature of the Rayotube target as measured by a thermocouple, optical pyrometer or other accurate means. Subsequently, readjustment of the compensator will be required if target conditions change (by accumulation of deposits on target, for example) or if the Rayotube is focused on a different target. No readjustment of the compensator is normally required with target tube installations. Also, the compensator is not to be used to correct for inaccuracies caused by the accumulation of dirt on the Rayotube window — the Rayotube should be kept clean.

To make the compensator adjustment, simply rotate the compensator dial to obtain correct instrument reading.

GAS ANALYSIS INSTRUMENTS

Speedomax W instruments for use with 7802 Series thermal conductivity gas analyzers incorporate range and zero rheostats inside the case. After installation of the equipment, these rheostats must be adjusted to make the instrument reading agree with the known composition of samples passing through the analyzer cell. The recommended adjusting procedure is as follows:

(1) Initially, set the range and zero dials to the factory settings which appear on the data card of the analyzer cell cabinet.

(2) Prepare a gas mixture of composition approximately equal to the compensating point, as marked under COMP. on the analyzer data card. Pass this mixture through the analyzer cell assembly and adjust the zero dial until the Speedomax W reading corresponds to the composition of the mixture.

(3) Pass through the cell assembly a gas mixture of composition approximately equal to that end of the analyzer range which is farthest from the compensating point. Adjust the range dial until the Speedomax W reading corresponds to the composition of the mixture. If this necessitates moving the range dial by more than two divisions, repeat step (2) and adjust the range dial again. Repeat this procedure until further adjustment of the range dial is unnecessary.

Note: Some gas analyzer applications require modification of the foregoing procedure. Refer to the instructions furnished with the analyzer.

During operation the range and zero settings should be checked and adjusted as described above, approximately every two weeks. When repeated adjustments have caused the zero dial to depart from the factory setting by more than 30 divisions, the analyzer measuring cell must be cleaned as outlined in the instructions furnished with the analyzer.

Section D—CONTROL AND ALARM FEATURES

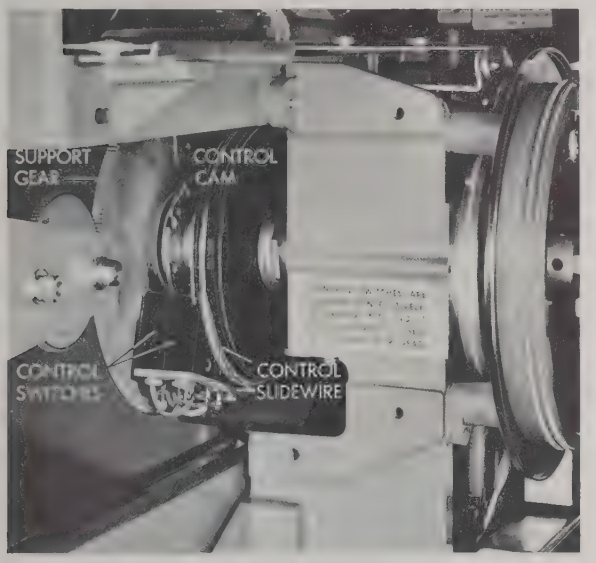


Fig. D1—Control assembly.

CONTROL ASSEMBLY

The Speedomax W instrument may contain one or more switches arranged to be operated by the rotation of the measuring slidewire shaft. If the instrument is to be used for proportioning control, a control slidewire, also rotating with the measuring slidewire shaft, is provided. The control slidewire and switches, together with associated cams, setting device, etc., form a complete assembly more or less similar to that shown in Fig. D1. Such an arrangement of components is called a *control assembly*. This designation applies even when the assembly performs some function other than control.

Any one of several combinations of switches and slidewires may be provided. The principal uses of such arrangements are:

Alarms — Switches can be connected to external circuitry to actuate alarms or other safety devices when certain preselected instrument readings are attained.

Simple Control — One or more switches can be used to turn a final control device on and off at predetermined readings and thereby control the variable being measured. This "on-off" or two-position method of control is described more fully in Section O.

Proportioning Type Control — When proportioning control is furnished, a slidewire of the type shown in Fig. D1 is provided. This slidewire is connected into the bridge circuit of a separate control unit which operates a final control element (through appropriate circuits) to maintain the measured variable at a preset value. Usually the measuring instrument and control unit form a "package" complete with all necessary internal wiring. Refer to the separate manual for the control unit.

Although the control assembly is *mechanically* part of the Speedomax W instrument, its wiring is entirely separate from that of the measuring circuit and balancing system. Therefore, the instrument can be placed in service, for measuring purposes, before any adjustments to the control assembly are made, and before control wiring is installed.

CONTROL SETTER

The control assembly consists of two principal parts—(1) an assembly of control slidewire and operating cams which rotate with the slidewire shaft, and (2) the corresponding sliding contact and switches, mounted on a support gear which is linked to the red control pointer. Both of these parts are equipped with adjustable clutches to permit the proper control settings to be made and retained.

The support gear, and hence the switches and slidewire contact, can be coveniently set to any desired position from the front of the instrument. As shown in Fig. D2, this is accomplished directly on the instrument by moving the control setter. The red pointer indicates the setting of the control components.

After proper initial adjustment of its cam, each control switch will be operated automatically whenever the instrument reading (black pointer) bears a certain predetermined relationship to the control setting (red pointer). Similarly, the position of the sliding contact on the control slidewire depends upon the relationship between red and black pointer positions. Thus the control setter provides convenient selection of control switch and slidewire operating points.

STATIONARY SWITCHES

Some instruments have cam-operated switches mounted directly on the hinged casting. Such stationary switches are independent of the control setter and the red pointer. Each stationary switch operates at a particular value of instrument reading which is determined by the setting of its operating cam.

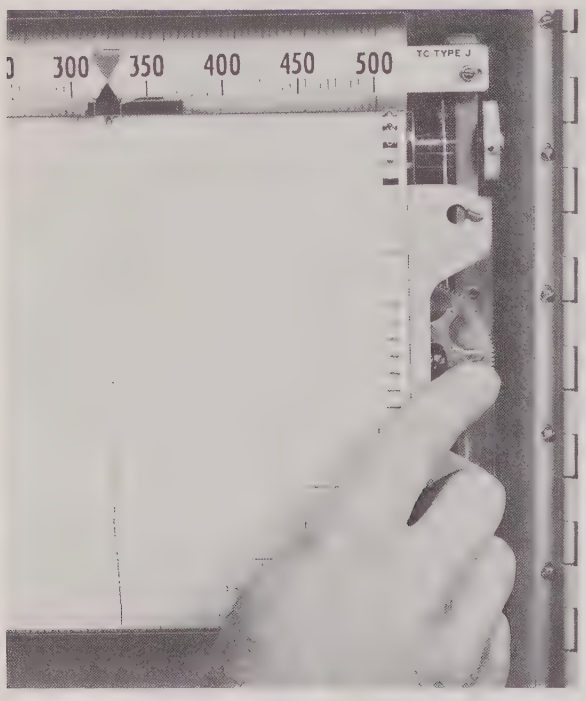


Fig. D2—Operation of the control setter.

CONTROL ASSEMBLY WIRING DIAGRAM

The internal wiring to the control assembly is not shown on the same diagram as are the measuring and motor circuits. Instead, a separate control wiring diagram is furnished. The circuit of a typical control arrangement is shown in Fig. D5.

To identify the correct control wiring diagram for a particular instrument, look at the instrument catalog number which is given on the nameplate inside the instrument case. This is a coded number, and its *third element* represents the internal control arrangement. The circuit of this arrangement is shown in the particular wiring diagram (Fig. D5) which is marked with the same number.

Example: If the instrument catalog number is:
500-901-176-0011-006-001-01
then the third element—176—is the control number. Fig. D5 shows the control wiring for the instrument.

In connection with the control wiring diagrams, note the following:

(1) When more than one control switch is present, the switches are numbered on the diagram. Numbering is in order of switch position, starting with No. 1 for the switch nearest the support gear.

(2) The contacts of control switches are designated H, L, and C, standing for high, low and common, respectively. Definitions of high and low contacts are as follows:

A *high* contact is one which is closed by an *upscale* motion of the instrument pen or pointer.

A *low* contact is one which is closed by a *downscale* motion of the instrument pen or pointer.

(3) When an auxiliary relay is provided as part of the control circuit, this relay is located in the rear of the instrument case, above the range card.

CONTROL SWITCH CHARACTERISTICS

Fig. D3 shows the standard type of control switch used in Speedomax W instruments. This is an spdt snap-action switch which is operated by the control cams. The switch has no stable open position—for any position of its cam, either the high or the low contact will be closed. Other pertinent characteristics of the control switch are as follows:

Differential gap of the switch is approximately 0.2% of full scale. This is the difference in the instrument readings required to produce low-to-high and high-to-low operation. For example, if upscale pointer motion causes the high contact to close at exactly midscale reading, then downscale motion will close the low contact (and thereby open the high contact) at a reading which is below the midscale value by a maximum of 0.2% of scale length. For all practical purposes this 0.2% gap is negligible—the switch can be considered to operate at the same reading for both upscale and downscale pointer travel.

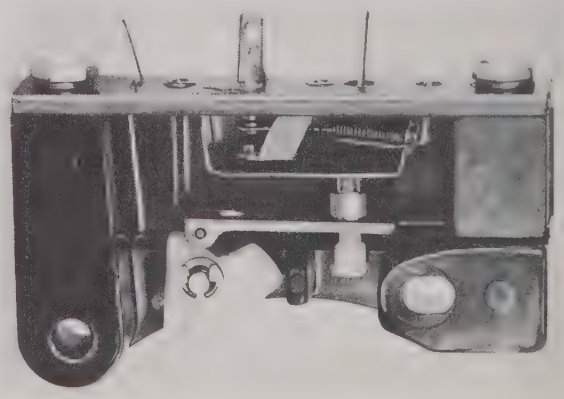


Fig. D3—Control switch.

Switch Capacity—The rated current interrupting capacity of the control switch is as follows:

A-C loads (non-inductive)	1.0 ampere at 120 v a-c 0.5 ampere at 240 v a-c
D-C loads (non-inductive)	0.1 ampere at 120 v d-c 0.05 ampere at 240 v d-c

Inductive loads—No rating can be given since capacity depends upon characteristics of the load and associated circuits.

PRELIMINARY CONTROL ADJUSTMENTS

Checking Pointer Position—Before proceeding with other adjustments, turn the control setter first in one direction and then the other. The red control pointer should be able to move over the entire scale. If it cannot, loosen the pointer clamp screw and turn the control setter clockwise until the mechanical stop is reached. Then move the pointer until it is about 1/16" above the first line of the scale, and clamp it to its drive cord.

Control Switch Adjustment—When adjusting control switches, connect an ohmmeter to the appropriate tie point terminals (see Fig. F6) to determine when

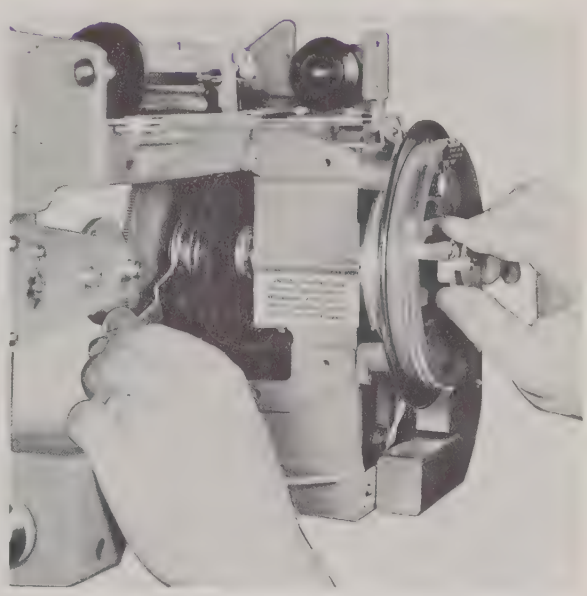


Fig. D4—Use of wrench to adjust control cams.

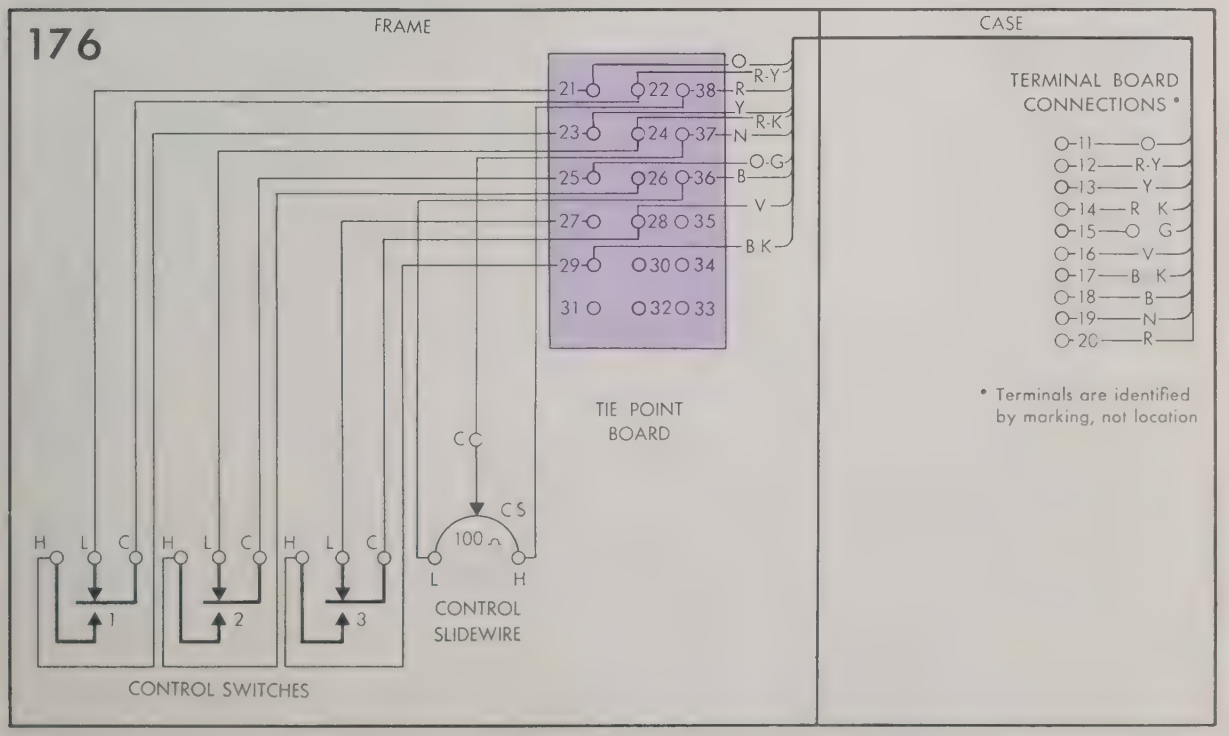


Fig. D5—Internal control wiring for three control switches and a control slidewire.

switching action occurs. Turn off all power to the instrument before making adjustments. The instructions given here apply to each switch of the control assembly.

Actual adjustment of the control cams is made with a specially-designed wrench supplied with the instrument. Fig. D4 illustrates the use of this tool.

If the switch is control setter operated, first bring the red pointer to a main division near the center of the scale. Then manually rotate the slidewire contact arm to bring the black pointer to the reading at which switch operation is desired for the red pointer setting which has been selected. While holding the arm in this position, turn the appropriate switch cam on its sleeve to the point where switching action occurs.

Adjustment of a stationary switch is as just described except that the red pointer setting is immaterial. Simply set the black pointer to the scale reading at which the switch is to operate, and adjust its cam as instructed above.

Control Slidewire Adjustment—For the proper adjustment of the control slidewire, refer to the manual for the control unit. Usually, the control slidewire contact must be at, or slightly above, the center of the slidewire when the red and black pointers are in line. Rotate the control slidewire on its sleeve until this condition is obtained. While making the adjustment, use an ohmmeter to measure the position of the sliding contact on the slidewire.

CONTROL WIRING ARRANGEMENTS

Fig. D5 is a wiring diagram of a frequently used control arrangement. Since many different types of control arrangements are available—too many to be covered in a single manual—the control arrangement for an instrument is provided on a diagram supplied with that instrument. Wiring connections to the user's equipment should be made in accordance with that diagram. Each diagram shows only the external connections to the Speedomax W terminal board, and specifies the various internal arrangements with which the external circuitry is suitable. It may be that for some combinations, not all of the control switches in the instrument are used. If desired, such switches can be employed to operate alarms, signals, etc.

For a discussion of two types of control—two-position single point and two-position differential gap, refer to Section O.

Section E—ROUTINE MAINTENANCE

This section covers the few routine maintenance procedures required during normal operation of the instrument.

CARE OF THE PEN

Refilling—It is recommended that the pen be refilled when the ink level falls within ¼″ of the bottom of the reservoir. In no case should the pen be allowed to run completely dry since this necessitates reprimming, and may also permit ink to dry inside the capillary with consequent clogging of the pen.

The refilling procedure is identical to the initial filling operation, except that priming is not required.

Failure of Pen—If the pen stops inking while the reservoir still contains sufficient ink, it may be possible to start the ink flow by one of the following methods:

—Moisten a finger and draw it across the penpoint.

—Repeat the priming procedure.

If neither of these methods is successful, insert one of the fine wires (supplied with the instrument accessories) in the back (reservoir end) of the pen capillary and push it through the capillary to clean out any particle clogging it. The pen must be primed when the capillary is replaced.

In extreme cases, where the ink still does not flow, remove the clogged pen and install a new one. Place the clogged pen in alcohol or hot water for a short time and then insert a cleaning wire as previously directed. Fill the ink dropper with alcohol or hot water, fit its spout over the penpoint, and force the fluid through the capillary. Allow both the pen and dropper to dry thoroughly before using. If ink has been allowed to dry in the pen, the reservoir should also be cleaned with hot water before further use.

CLEANING AND LUBRICATING

Since the Speedomax W is a continuously operating mechanism, occasional cleaning and lubricating are required. The schedule given below should be followed under normal conditions of use. Where the instrument location is very dusty, more frequent cleaning and lubricating may be necessary.

Cleaning—The following cleaning operation should be performed every two months.

Measuring Slidewire—Rub a clean cloth, moistened with benzene, over the contacting surfaces of the measuring slidewire. If the instrument location is such as to prohibit the use of benzene, carbon tetrachloride may be used sparingly. *Do not apply any lubricant to the measuring slidewire.*

Pen Carriage Shaft—Place a small quantity of oil on a cloth and rub the pen carriage shaft with it until the shaft is clean. Leave a thin film of oil on the shaft for lubrication. A screwdriver slot at one end permits the pen carriage shaft to be unscrewed a half turn for cleaning of the underside, or the shaft can be removed entirely for cleaning. Make sure to replace and tighten the shaft properly after cleaning. If the shaft has been removed, check the pen lineup as instructed in Section H and readjust the pen if necessary.

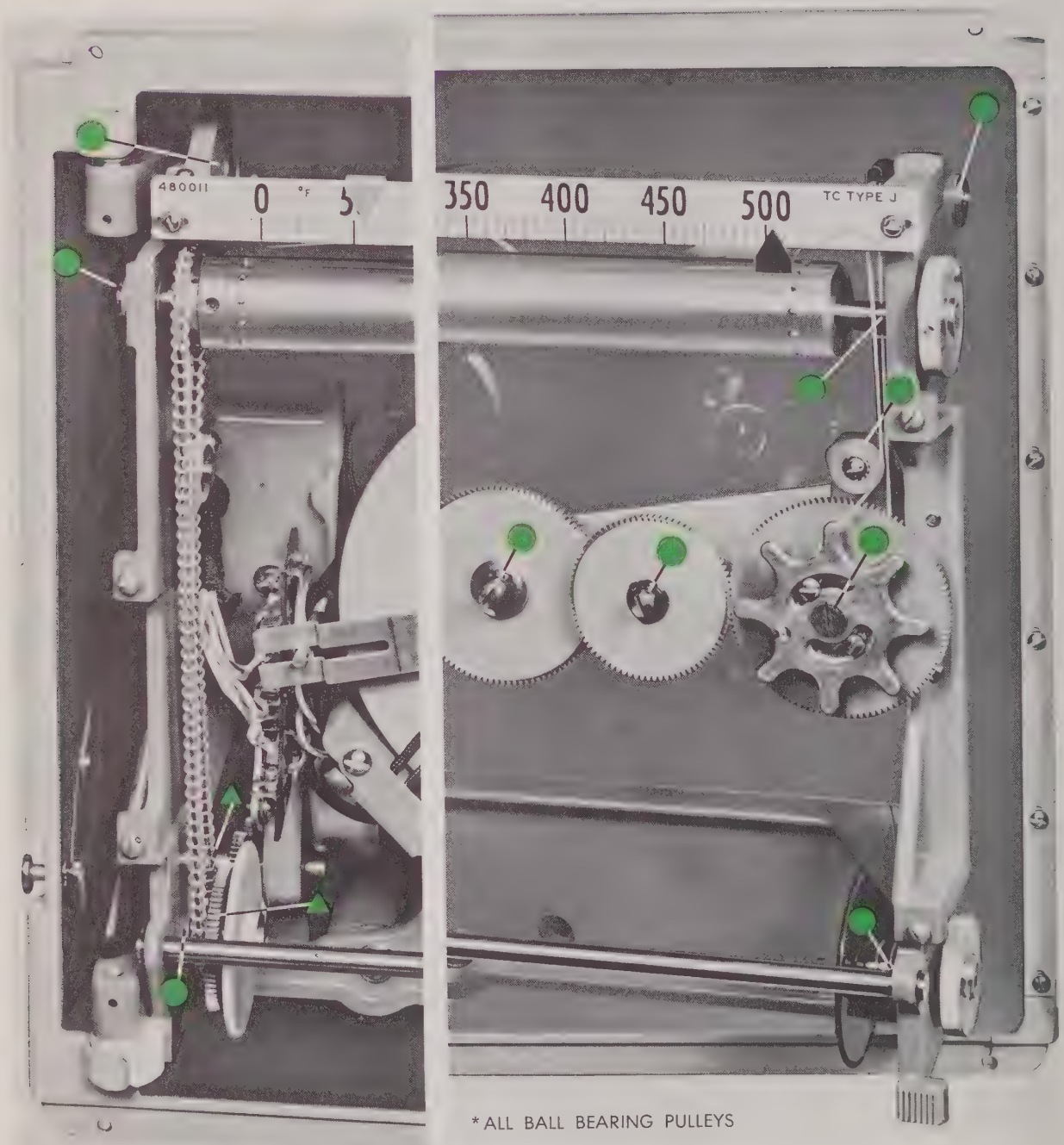
Clutch and Gear Assembly—The clutch and gear assembly, Fig. F6, should be removed and cleaned every six months. Turn the instrument off and remove the chart and chart platen. Remove the screw from the center of the clutch and gear assembly, Fig. F6—this screw has a *left-hand* thread—and lift out the assembly.

Use the Standard Pliers No. 2 and remove the retaining ring from the end of the assembly. Lift off the bronze washer, the large friction disk and the smaller friction washer. Thoroughly clean the friction disk and friction washer and reassemble the parts. In doing this, see that the notch in the friction washer lines up with the small hole in the part to which the gear is attached. Keep this friction washer in this position while replacing the friction disk, bronze washer and retaining ring.

Replace the assembly and hold it in place with the screw. Note that the gears mesh properly and see that the drive chain is fitted back of the guide wheel on the frame casting.

Lubrication—Use a good grade of medium weight, nondetergent oil, e.g., L&N recorder oil, to lubricate the points indicated in Fig. E1. Place on only one or two drops of oil at a time and wipe off any excess. On the ball bearing pulleys, be particularly careful that no oil gets on the drive cord(s) as this may accelerate wear of the cord(s).

A more suitable method of lubricating exposed parts, such as gear teeth, cams, etc., is to use a #3 or #4 artist's brush. Dip the brush in oil, remove the excess by wiping across the lip of the container once, and then apply the oil-filled brush to the exposed part(s).



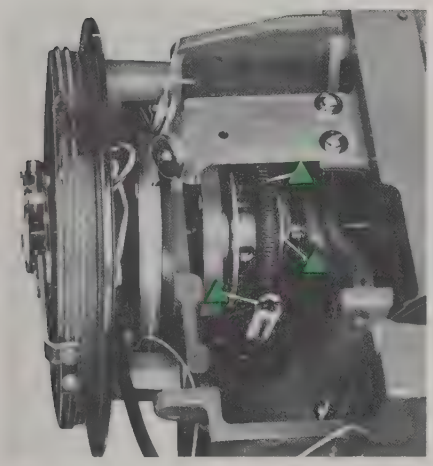
FRONT STRUCTURE

Fig. E1—Lubrication schedule.

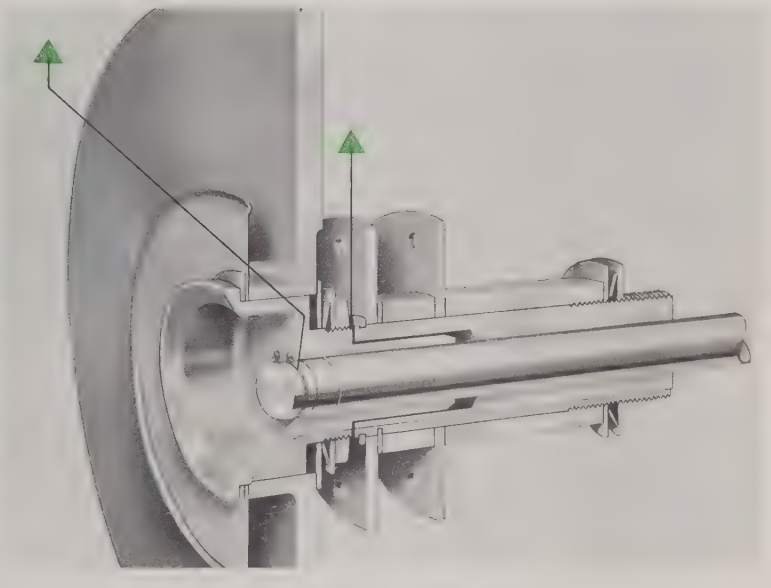
CAPACITOR REPLACEMENTS

Since electrolytic capacitors are among the instrument components most likely to fail, it is advisable to carry on hand replacements for the two electrolytics used in the instrument amplifier. These are the two cylindrical plug-in units located on the amplifier chassis.

Electrolytic capacitors are particularly subject to deterioration when not in use. Therefore if spares are carried, they should be substituted for the capacitors in the instrument at six-month intervals. This will insure that good replacements are available in case of failure.



MOTOR WORM
AND WORM GEAR
AND
WORM GEAR CLUTCH



CONTROL ASSEMBLY
ALL INSTRUMENTS HAVING CONTROL

▲ LUBRICATE EVERY 2 MONTHS
● LUBRICATE EVERY 6 MONTHS

Fig. E1 concluded.

Section F—REMOVAL AND INSTALLATION OF PARTS

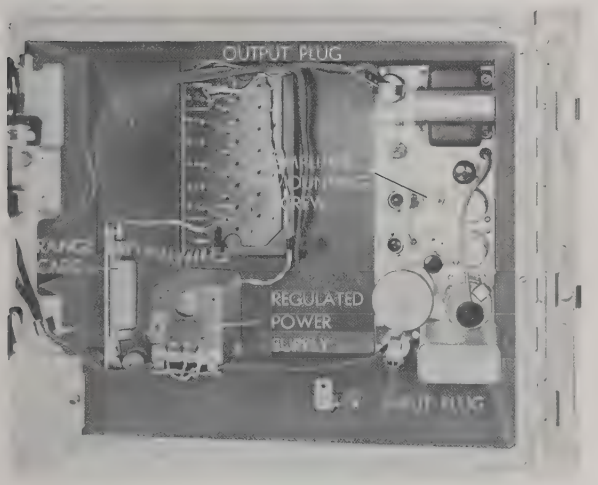


Fig. F1—Interior of case.

In servicing the instrument, it may be necessary to remove one or more parts. This section describes and illustrates such partial disassembly operations and also indicates, where necessary, the replacement or installation of the parts. In all cases where several steps are required to effect a removal or replacement, these steps should be followed *in the order given.*

TOOLS

A special control wrench and a set of Allen wrenches are supplied with the instrument. With the single exception mentioned below, no other special tools are needed for working on the instrument.

A number of Waldes Truarc retaining rings are used in assembling the parts. To facilitate removal or installation of these devices, the following tools, designed specifically for the purpose, should be available:

Alternate Field Pliers No. 0—for small external retaining rings (No. 12 to No. 23).

Standard Pliers No. 2—for all other external rings in the instrument.

Standard Pliers No. 1—for internal ring (used only to retain slidewire shaft bearing in hinged casting).

If not otherwise available, these pliers may be ordered from Waldes Kohinoor, Inc., Long Island City 1, New York.

RANGE CARD

Electrical connections to the range card are made through a plug-in connector. Thermocouple range cards, in addition, include compensating leadwires which connect to the input terminals on the front (back side) of the terminal board. A slot in the bottom of the terminal board permits the leadwires to be brought through for connection. See Fig. F1.

To remove the range card, simply loosen the thumbscrew and pull the card forward. See Fig. F2. On thermocouple types, it will be necessary to disconnect the leadwires from the terminal board first.

To replace the range card or install a new one, reverse the above procedure. Be careful to observe polarity when connecting leadwires for thermocouple types, where applicable.

AMPLIFIER

The single-post mounting of the amplifier permits convenient removal for servicing or replacement. First, pull out the amplifier input (lower) and output (upper) plugs. Then unscrew the knurled mounting screw to free the amplifier. Withdraw the amplifier by lifting it slightly and pulling it straight out.

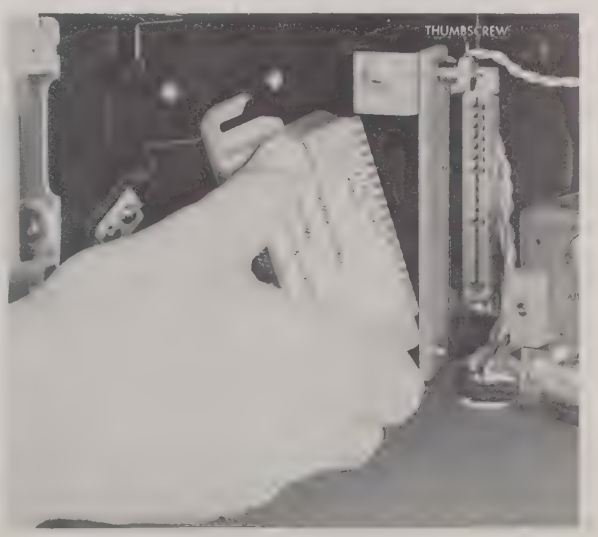
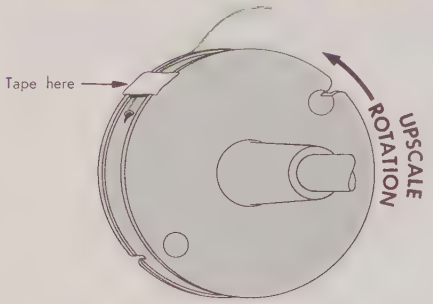
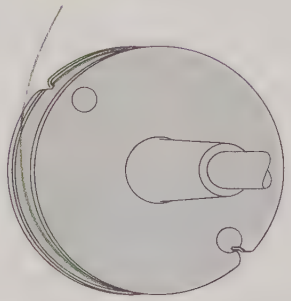


Fig. F2—Removing range card.

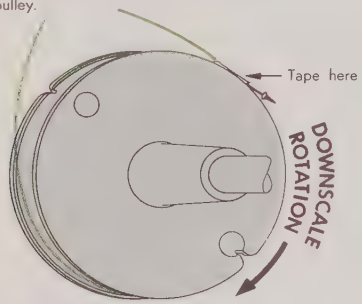


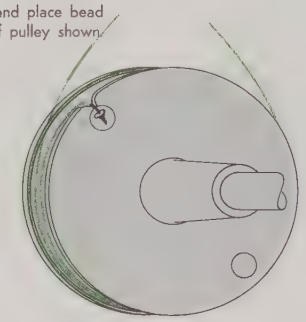
1—With slidewire arm turned to low end stop, tape one end of cord to large pulley on measuring slidewire shaft. Now rotate measuring slidewire shaft in upscale direction to carry end of cord down around pulley.



2—Detach tape and place bead in front slot of pulley (i. e. slot nearest chart assembly).

4—Detach tape and place bead in rear slot of pulley shown.

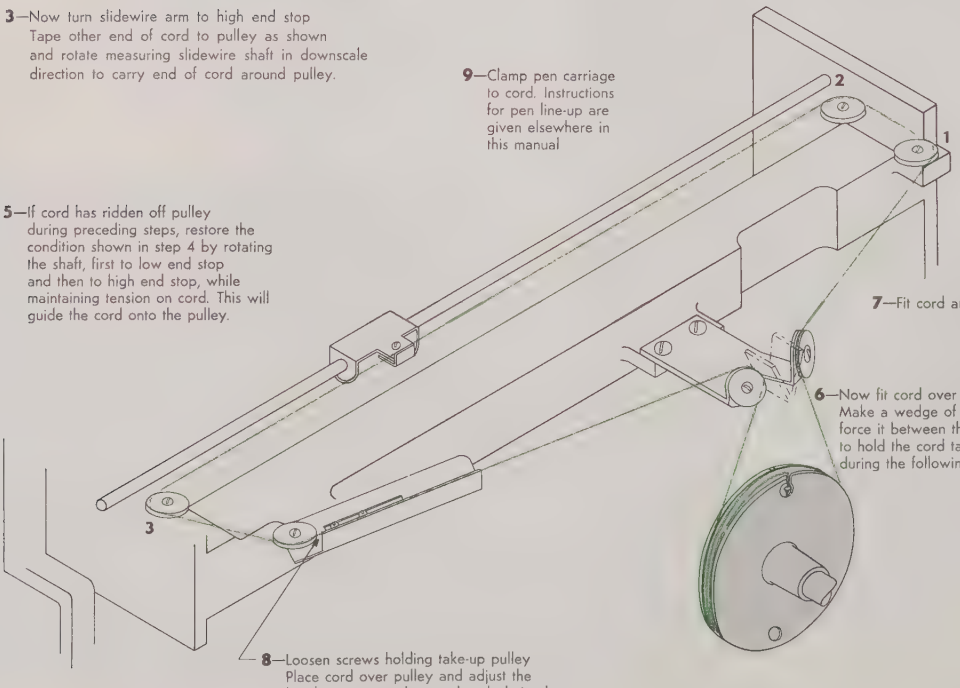




3—Now turn slidewire arm to high end stop Tape other end of cord to pulley as shown and rotate measuring slidewire shaft in downscale direction to carry end of cord around pulley.

9—Clamp pen carriage to cord. Instructions for pen line-up are given elsewhere in this manual

5—If cord has ridden off pulley during preceding steps, restore the condition shown in step 4 by rotating the shaft, first to low end stop and then to high end stop, while maintaining tension on cord. This will guide the cord onto the pulley.



7—Fit cord around pulleys 1, 2, 3.

6—Now fit cord over these two pulleys. Make a wedge of folded paper and force it between the pulleys as shown to hold the cord taut on the main pulley during the following steps

8—Loosen screws holding take-up pulley Place cord over pulley and adjust the bracket to just take up the slack in the cord and no more

Fig. F3—Installation of pen drive cord. All views of main pulley are from rear of instrument.

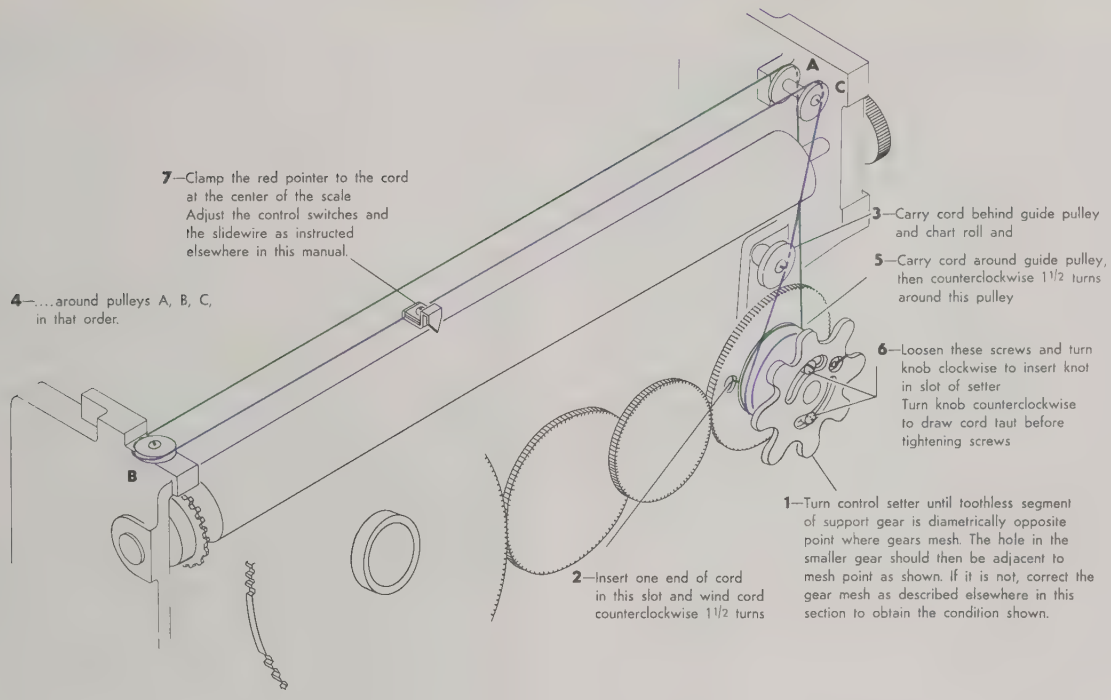

A
C
B
7—Clamp the red pointer to the cord at the center of the scale Adjust the control switches and the slidewire as instructed elsewhere in this manual.
4—....around pulleys A, B, C, in that order.
3—Carry cord behind guide pulley and chart roll and
5—Carry cord around guide pulley, then counterclockwise 1 1/2 turns around this pulley
6—Loosen these screws and turn knob clockwise to insert knot in slot of setter Turn knob counterclockwise to draw cord taut before tightening screws
1—Turn control setter until toothless segment of support gear is diametrically opposite point where gears mesh. The hole in the smaller gear should then be adjacent to mesh point as shown. If it is not, correct the gear mesh as described elsewhere in this section to obtain the condition shown.
2—Insert one end of cord in this slot and wind cord counterclockwise 1 1/2 turns

Fig. F4—Installation of control setter drive cord.

When replacing the amplifier plugs, note that the handle of the upper plug must be horizontal, while that of the lower plug is vertical. The plugs can be engaged only when in the correct positions.

DRIVE CORD REPLACEMENT

Pen Drive Cord—Remove the chart, the pen capillary assembly, and all pieces of the old cord and install the new cord according to the sequence of steps given in Fig. F3. Then adjust the scale, pointer, and pen lineup as instructed in Section H and also check for dead band as instructed in Section H.

Control Setter Drive Cord—Remove the chart, chart platen, and all pieces of the old cord and install the new cord according to the sequence of steps given in Fig. F4. Then adjust the red pointer position and the control settings as instructed in Section D.

SLIDEWIRE ASSEMBLY

Caution: In removing or replacing any parts of the slidewire assembly, be careful not to damage the slidewire itself. In particular, do not allow the contacts to snap down on the slidewire since this may nick the wire and affect the instrument calibration.

Slidewire Contacts—To remove the contacts only, take out the two screws which hold the contacts and the small metal clamp plate to the end of the contact arm. When replacing the contacts or installing new ones, take care that each contact is centered over its corresponding slidewire.

When the slidewire contacts have been replaced, the contact setting should be checked as instructed in Section H.

Contact Arm—To remove the contact arm, loosen the socket-head capscrew and slide the arm from the end of the shaft. Take care not to bend the contact springs.

When reinstalling the contact arm, each contact must be centered over the corresponding slidewire. Also, the arm should not touch either the slidewire molding or the slidewire cover when this cover is replaced.

The contact arm is keyed to go on the shaft in the correct position. After replacing the arm, check the contact setting as instructed in Section H.

Slidewire—To free the slidewire, first remove the contact arm and then take out the two slidewire

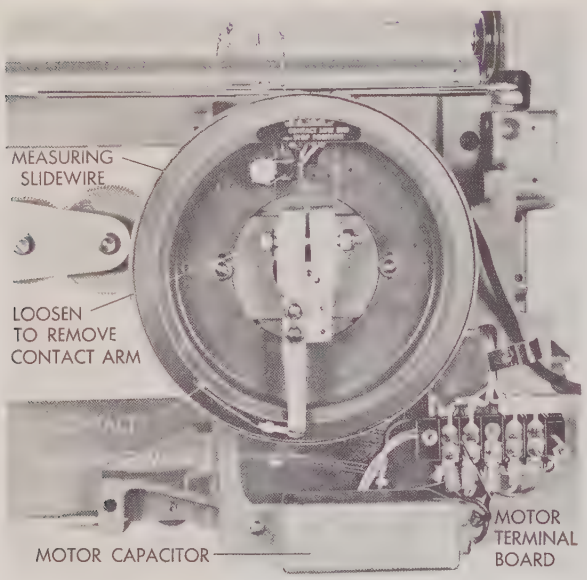


Fig F5—Rear view of hinged casting.

mounting screws. The complete slidewire molding, together with the rear slidewire shield, may now be removed.

When the slidewire is replaced, the contact setting should be checked and adjusted as instructed in Section H.

BALANCING MOTOR

To remove the balancing motor, first disconnect the motor leadwires at the motor terminal block. Then take out the three screws which hold the motor to the nutplate. Two of these screws are accessible from the bottom, the third from the top. The bottom screws to be removed are identified by the location of tapped holes in the nutplate.

The balancing motor can now be withdrawn through the bottom of the hinged casting. See Fig. F5.

When replacing the balancing motor or installing a new one, first orient the motor so that its nameplate faces the hinged side of the casting. Then replace the screws, adjusting the position of the motor and nutplate while tightening the screws, so as to obtain a good mesh with minimum backlash between the motor worm and the fiber worm gear on the slidewire shaft. See Section G for instructions on checking this mesh.

Finally, reconnect the motor leadwires to their appropriate terminals on the motor terminal block.

CONTROL ASSEMBLY

Control Setter Assembly—Refer to Fig. F6 for identification of parts.

Remove the chart platen and flexible leadwire clamp.

Now, upon removal of the retaining ring from the front of the slidewire shaft, the control setter support gear, together with any control switches and slidewire contacts, can be withdrawn from the shaft. *Depress the control switch operating levers when withdrawing this assembly, to clear the control cams and prevent damage to switches. Care must also be exercised to prevent damage to the control slidewire.*

When replacing the control setter, the support gear must be properly meshed with the smaller intermediate gears and the setter gear. The correct condition of mesh is illustrated in Fig. F4.

If adjustment of gears is required, this may be done by loosening the mounting nut on the back of the gear shafts. See Fig. D1. Loosen the intermediate and control setter gears. Then starting with the gear next to the support gear, work toward the control setter gear, tightening each gear after the proper mesh with its mating gear has been obtained.

Check gear alignment also: the teeth of one gear should completely mesh with the mating gear(s). If not, the intermediate gears may be adjusted by moving the lockring (see Fig. F6) on the gear shaft in or out as required to bring the gears into proper mesh.

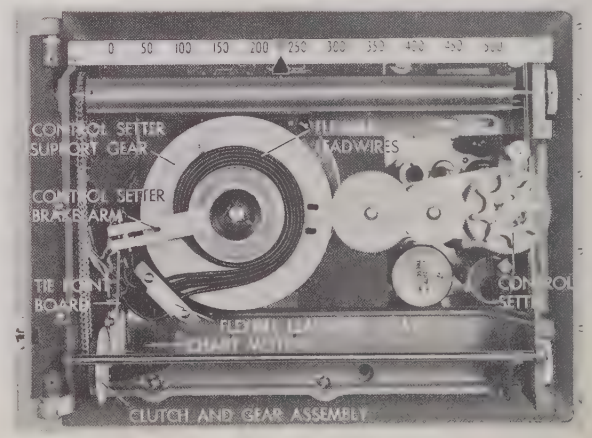


Fig. F6—Instrument with chart platen removed.

After the support gear is replaced, the flexible leadwires are to be wound clockwise from the hub out. With the control setter turned to its counter-clockwise (downscale) limit, the flexible leadwires must be wound snugly around the hub in a single layer, as shown in Fig. F6, before the leadwire clamp is mounted. The brake arm must engage the pin as shown.

Upon replacement of the control setter assembly, the settings of control switches and/or slidewires should be checked and readjusted as directed in Section D.

Control Slidewire and Cam Assembly—With the control setter assembly removed as described above, the control slidewire and cam assembly can be removed as a unit by loosening the setscrews, Fig. G2, which hold the mounting sleeve to the slidewire shaft.

Upon replacement or installation of a control slidewire and cam assembly, mount the control setter assembly before tightening the setscrews in the sleeve. Then with the support gear pulled forward against the retaining ring, adjust the sleeve to allow from .005″ to .01″ clearance between the sleeve and the support gear. Hold the sleeve in this position and tighten the setscrews onto the flats of the shaft. The clearance is to prevent binding of the assemblies during operation.

CHART MOTOR

With the instrument turned off, disconnect the chart motor leads at the motor terminal board. Remove the chart and chart platen. Then take out the screw from the center of the clutch and gear assembly, Fig. F6—this screw has a *left-hand* thread. Remove the clutch and gear assembly temporarily. Also remove the E washer from the left-hand end of the lower chart guide shaft and slide this shaft to the right until it is about half way out. These last two moves are simply to provide more space for the removal of the motor.

Remove the two screws, Fig. F7, which secure the motor mounting plate to the casting. Lift the motor, pinion and plate, as a unit, out through the opening left by the removal of the clutch and gear assembly and by the sliding of the chart guide shaft.

To replace the chart motor, reverse the steps outlined above. Note that the motor pinion is to be mounted with its hub toward the end of the shaft.

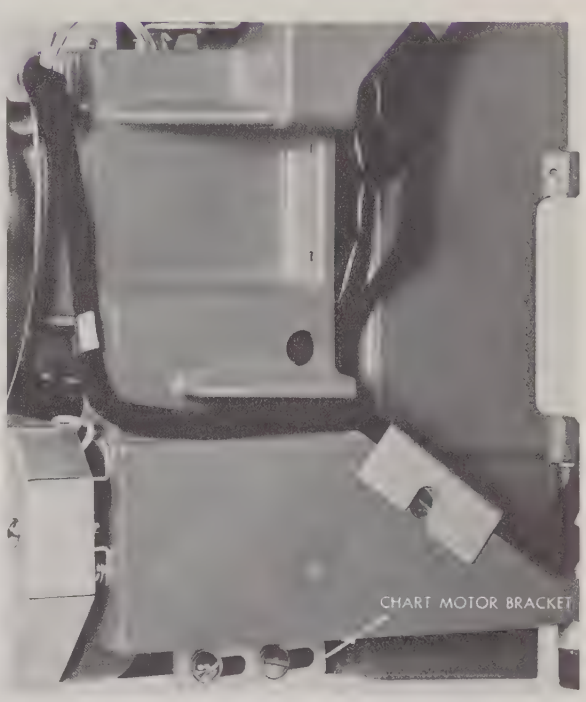


Fig. F7—Chart motor mounting screws are accessible from side of hinged casting.

Before tightening the motor plate mounting screws, adjust the position of the plate to obtain a good mesh with the idler gear. Check backlash by observing shake in the idler gear; check for binding by rotating the motor pinion manually in a clockwise direction, as viewed from the end of the motor shaft.

REGULATED POWER SUPPLY

To remove the regulated power supply, Fig. F1, disconnect the wires from the unit. Then remove the two screws at the bottom of the unit, to release it from the holder, and lift the unit from the holder.

To replace the regulated power supply or install a new one, hold the unit so that the pin in the rear fits into the hole in the rear side of the mounting bracket and the two screw holes in front line up with the two mounting screw holes in the front of the mounting bracket. Replace the two mounting screws and any cable clamps that were mounted under them; then tighten the mounting screws and reconnect the leads to their appropriate terminals.

Section G—MECHANICAL SERVICING

CONTACT FORCE ADJUSTMENTS

Caution: In making the following checks and adjustments, take care never to allow contacts to snap down on slidewires since this may cause nicking of the slidewires and affect calibration.

Measuring Slidewire – Each of the contacts should bear against the slidewire with a force of 2-3 oz. If the contact force is too low, unreliable electrical connection may result. Excessive force will cause rapid wearing of the contacts.

When the contacts are disturbed or new ones installed, the contact force should be measured and adjusted if necessary. Use a spring scale with an L-shaped hook on the end to make the measurement. With the instrument turned off, apply a straight pull perpendicular to the contact spring as shown in Fig. G1. If the force required to just lift the contact off the slidewire is not within the limits 2-3 oz. (56-84 grams), the force should be adjusted. Excessive contact force can be relieved by bending the contact outward without removing it from the instrument. To increase the force, the contact must be removed, bent, and reinstalled. After the contacts are reinstalled, the instrument calibration should be checked as instructed in Section H.

Control Slidewire—The contact is set to bear against the control slidewire with a force of 2-3 oz. The contact force is measured with a spring scale, using the same method as has been described for the measuring slidewire contacts.

First, turn off *all* power to the instrument. Then turn the control setter to make the control contact accessible. Rotate the slidewire shaft (by turning the hub of the measuring slidewire contact arm) until the contact rests on the wrapped portion of the control slidewire mandrel—not on the molding. Apply a straight radial pull to the contact leaf, adjacent to the contact itself. If the force needed to just lift the contact from the slidewire is not within the limits 2-3 oz. (56-84 grams), readjustment is necessary. Excessive contact force can be relieved by bending the contact away from the slidewire. To increase the force, the contact must be removed, bent, and replaced.

CLUTCH ADJUSTMENTS

Speedomax W instruments employ several clutches, as shown in Fig. G2. Each clutch consists of a spring washer arranged to be compressed by an adjustment nut. The clutches will not require adjustment unless they are disturbed. When necessary, the factory settings can be restored as instructed below.

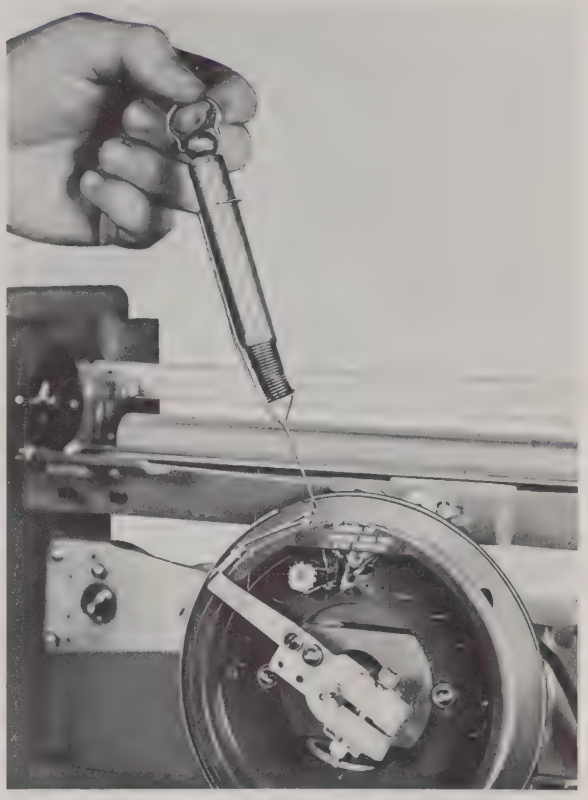


Fig. G1—Slidewire contact force measurement.

Worm Gear Clutch—This clutch may be tightened to the point where it just stops the motor from turning when either mechanical limit stop is reached. However, the clutch should never be so tight that the fibre gear is locked to the shaft. Impress a signal on the recorder of sufficient magnitude to have the motor drive the mechanism against one mechanical limit stop with full torque. Observe the slip action. Adjust the clutch so that the motor still drives when the stop is reached but then stalls or barely rotates after several revolutions of the fibre gear.

Control Setter Clutch—This clutch is identified in Fig. G2. When it is properly adjusted, an applied torque of 5-7½ lb.-in. is required to turn the control setter support gear. To adjust, turn the control setter to bring the red pointer on scale. Then use a spring scale

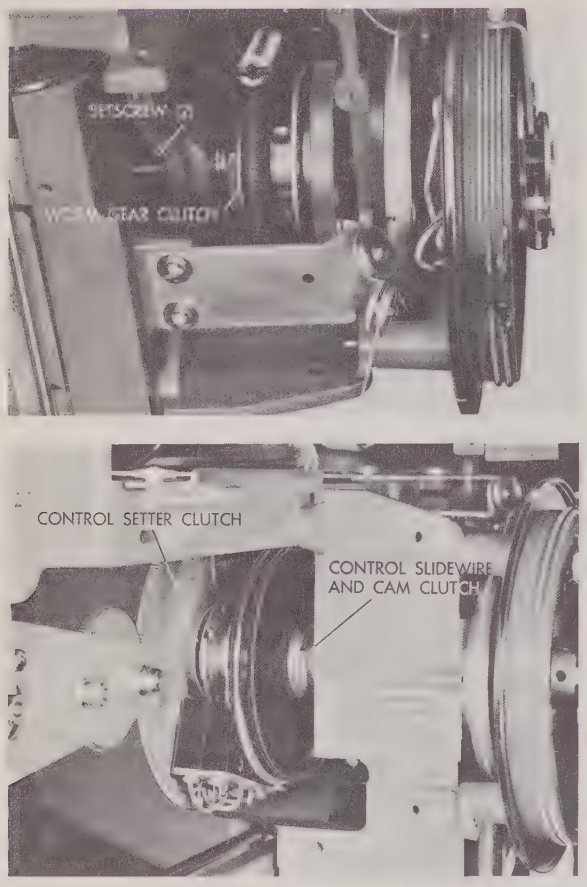


Fig. G2—Speedomax W clutches and control slidewire and cam assembly (instrument viewed from top and side).

to apply a tangential pull to one of the finger notches of the setter as shown in Fig. G3. The pull required to move the red pointer should be from 3 to 4 lbs. If it is not, adjust the nut to obtain the correct condition.

Control Slidewire and Cam Clutch – This clutch is identified in Fig. G2. To adjust the clutch, first tighten the nut with moderate force, i.e., until the spring washer is completely flattened. Then back off the nut one flat from tight.

MOTORS

Chart Motor—This synchronous motor cannot be repaired. If the motor fails to operate for any reason, it must be replaced with a new motor of the same voltage, frequency, and speed. Refer to Section F.

Balancing Motor—The two-phase balancing motor is equipped with end-sealed type ball bearings properly packed with grease before leaving the factory. They should, therefore, require no attention for at least a year and possibly two years. It is recommended that no lubricant be added to the bearings and that the bearings be replaced with new ones when they become objectionably noisy.

To replace the bearings, first remove the motor from the instrument as instructed in Section F. Then loosen the hex nut to remove the worm from the end of the motor shaft. Remove the two (diagonally opposite) through bolts which hold the motor end covers in place and tap the shaft end cover

Fig. G3—Measurement of control setter clutch torque.

to loosen it. Remove this cover, noting the arrangement of any spacers, washers, etc., on the motor shaft. Lift the rotor from the motor frame, noting the arrangement of any spacers, washers, etc., on this end of the motor shaft.

Use a bearing puller to remove the old bearings from the rotor shaft. Press the new bearings (Leeds & Northrup Part No. 008052, packed with grease) on the shaft, taking care to apply pressure to the inner ball race only. The bearings must be pressed tightly against the shoulders on the shaft.

There is a slotted screw plug in one end cover of the motor for adjusting end shake. Before reassembling the motor, back this adjusting screw out (counterclockwise) approximately ¼ turn. This is accomplished in different ways, depending upon the motor being used. On some motors a large locking nut, around the adjusting screw, must be loosened to permit the adjusting screw to be turned. The locking nut must be tightened after the adjusting screw is set as outlined below. On other motors a small setscrew holds the setting of the adjusting screw and must be loosened before the adjusting screw can be turned. The setscrew must be tightened after the adjusting screw is set as outlined below. On still other motors there is no locking nut or setscrew. On these motors the adjusting screw is held by a plastic sealer (Loctite, Grade E) in the threads of the adjusting screw. To loosen the adjusting screw, simply apply sufficient torque on the screwdriver to break the seal. A drop of Loctite, Grade E, must be placed around the periphery of the adjusting screw, after it is set as outlined below, to hold the adjustment.

After the adjusting screw is backed out, replace the spacers, washers, etc., on the shaft in the original sequence and reassemble the motor. Then turn the end shake adjusting screw in until end shake of the rotor is *just* eliminated. *Do not turn this screw in beyond this point.* It is suggested that the adjusting screw be turned 1/16" (on the periphery of the screw) at a time for each check for end shake. After end shake is just eliminated, back out the adjusting screw 1/16" (on the periphery of the screw) and lock it in this position with the locking nut, setscrew, or Loctite, depending upon the type motor being serviced.

Replace the worm on the motor shaft and tighten in place with the hex nut. Then replace the motor as instructed in Section F, taking care to maintain proper mesh between gears as outlined below.

BALANCING MOTOR GEAR MESH

The balancing motor worm must mesh with the worm gear without binding and with minimum backlash. To check this condition, first check that the worm is centered on the teeth of the worm gear. Then use a screwdriver to turn the worm. This worm should rotate freely for all positions of the measuring slidewire shaft.

To check backlash in the gear mesh, feel the lost motion in the measuring slidewire contact arm. For any position of the arm, the lost motion should not exceed .020" as measured at the measuring slidewire contact. This is approximately equivalent to one of the fine wire turns on the measuring slidewire.

Section H— CALIBRATION

This section outlines proper procedures for checking calibration accuracy of the Speedomax W instrument. Such an accuracy check will be required when measuring circuit components are disturbed — e.g., after removal and replacement of the measuring slidewire, installation of new slidewire contacts, etc. The user may also wish to check the calibration periodically.

PRELIMINARY

Before proceeding with the calibration check itself, perform the following checks and adjustments regardless of the kind of measuring circuit used in the instrument. In addition, make sure that the instrument has warmed up for at least 30 minutes.

On instruments with low millivolt spans (2 mv or less), avoid the unnecessary use of terminal lugs or clips on any connecting leadwires. On thermocouple instruments it is advisable to wrap the incoming leadwires directly around the screw terminals and tighten securely.

SCALE, POINTER, AND PEN LINEUP

The instrument should be turned off during the following checks.

Turn the hub of the slidewire contact arm to bring the pen downscale until the penpoint is on the first calibrated line of the chart. Under this condition the pointer should be on the first calibrated line of the scale. If it is not, loosen the screws holding the scale and move the scale until the pointer is on the first calibrated line.

Next, turn the hub of the slidewire contact arm until the low-end mechanical stop is reached. The pointer should now be on the dot below the first calibrated line on the scale. If it is not, loosen the screw which holds the pen carriage to the drive cord and slide the carriage along the cord until the required condition is obtained. Then tighten the screw on the carriage to hold the alignment.

CONTACT SETTING

Before proceeding further, check the setting of the measuring slidewire contact as follows:

Turn the hub of the slidewire contact arm to bring the pointer downscale until the mechanical stop is reached. With the arm held against the stop, observe the position of the contacts on the slidewire. As shown in Fig. H1, this position should be such that

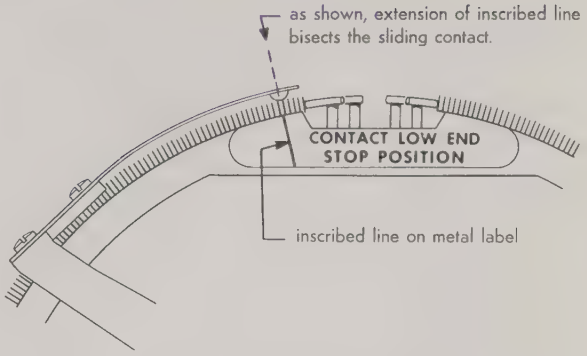

as shown, extension of inscribed line bisects the sliding contact.
CONTACT LOW END STOP POSITION
inscribed line on metal label

Fig. H1—Preliminary setting of measuring slidewire contacts.

the contact is bisected by the extension of the line inscribed on the slidewire molding. This line was inscribed at the factory after the instrument was calibrated.

If the position of the contacts on the slidewire is not as shown, loosen the two screws securing the slidewire molding and rotate the molding slightly to obtain this condition. Then retighten the screws.

INSTRUMENT DEAD BAND

If the various components, both electrical and mechanical, have been properly adjusted, the dead band should be negligible, i.e., 0.15% or less of full scale on most instruments. It is advisable however to make a direct check of instrument dead band before proceeding with calibration since excessive dead band may appear as a calibration error.

Dead band can be defined functionally as the difference between the final instrument readings for upscale and downscale approach to balance, respectively, the measured quantity being the same in each case. Thus dead band is measured by manually displacing the instrument reading, first downscale and then upscale, and observing the balancing action.

Because of the small dead band of the Speedomax W, it is more convenient, when measuring dead band, to observe the position of the balancing motor worm, rather than reading directly on the instrument scale or chart.

On instruments with a 5-second step response, one revolution of the worm on the balancing motor shaft is equivalent to about 1% change in instrument reading; for a 1-second step response, 1/6 revolution is about a 1% change. A screwdriver slot is provided in the motor worm to permit manual rotation.

Caution: The dead band check given here is not valid if there is excessive backlash in the mesh of motor worm and worm gear. Check this mesh as instructed in Section G.

With the instrument turned on, apply a fixed input to its measuring terminals to bring the reading on scale. Then check the dead band as instructed in Fig. H2. The dead band, measured in this manner, should be 45 degrees (approximately 0.15% of full scale) or less for any 5-second balance instrument whose millivolt range span is 8 mv or greater. For spans below 8 mv, with 5 seconds balancing, the permissible dead band will be proportionately greater than 45 degrees.

The above figures also apply to circuits using the high-gain type amplifiers except that in this case 2 mv applies where 8 mv now appears.

A dead band in excess of the 45 degrees (approximately 0.15% of full scale), as measured above, can usually be corrected by replacing badly worn measuring slidewire contacts, by increasing the amplifier gain or by adjusting any binding in the mechanical components of the balancing or indicating systems. Check and adjust or replace these items as indicated in Sections F, G, J, and K.

The millivolt range span of a potentiometer instrument can be determined from the data on the instrument nameplate. In the case of bridge instruments, calculate the resistance span from the nameplate data, and use the equivalent millivolt span—approximately equal to three times the resistance span in ohms—for determining the permissible dead band.

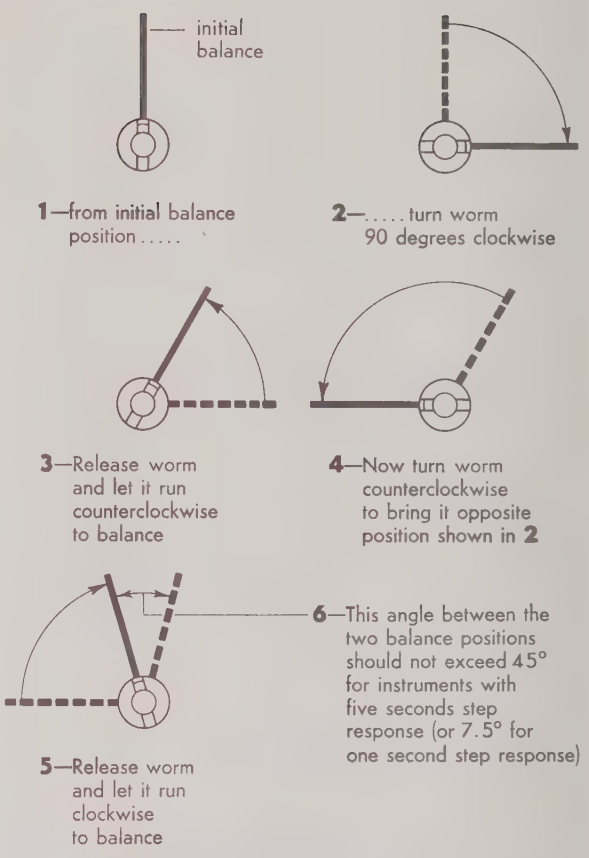

initial balance
1—from initial balance position . . . . .
2—. . . . . turn worm 90 degrees clockwise
3—Release worm and let it run counterclockwise to balance
4—Now turn worm counterclockwise to bring it opposite position shown in 2
5—Release worm and let it run clockwise to balance
6—This angle between the two balance positions should not exceed 45° for instruments with five seconds step response (or 7.5° for one second step response)

Fig. H2—Method of checking dead band by observing balancing action at balancing motor worm.

ZERO-OFFSET ADJUSTMENT

A zero-offset adjustment is provided on all instruments equipped with a moderate impedance amplifier (101120, 101121). Zero offset should be checked and adjusted if necessary just prior to instrument calibration, with the amplifier and power supply warmed up and the amplifier gain set at maximum.

Proceed as follows :

(1) Short the input to the recorder and the plus (+) and minus (—) terminals of the regulated power supply. If mercury cells are used instead of a regulated power supply, remove the mercury cells. With the pointer set at midscale, no pointer movement should occur. A slow movement of the pointer (pointer moving halfscale in 5 or 6 seconds or longer) will occur with an offset of only a few microvolts. Such an offset will be insignificant on most fixed-span instruments.

(2) If necessary, adjust the zero-offset potentiometer until there is no movement of the pointer as described in step 1.

To adjust, loosen the locknut on the offset potentiometer, Fig. B5 and, using a screwdriver, adjust the control until the above condition is obtained. Then tighten the locknut.

(3) Remove both shorts (or the input short, and replace the mercury cells), readjust the amplifier gain as previously directed, and then proceed to calibrate the instrument as instructed below.

CALIBRATION PROCEDURE

The exact procedures to be followed in checking calibration of a particular instrument will depend upon the kind of measuring circuit which the instrument employs. The remainder of this section outlines

the proper procedures for the most commonly used circuits.

In all cases, calibration is checked by measuring a reference standard. The validity of the check depends upon how accurately the reference value is known. It is therefore important that the accuracy of all reference sources used be considerably better than the accuracy requirements of the Speedomax W instrument.

Where the Speedomax W calibration is not within the required accuracy, the troubleshooting instructions given in Sections J and K will help to locate the fault. Calibration errors may be due to such causes as excessive amplifier offset, faulty regulated power supply, etc.

If the Speedomax W reading is outside the required accuracy by a small and constant amount, it can often be corrected by adjusting the position of the measuring slidewire. It is suggested that, when feasible, the calibration be checked at more than one point—preferably at the center and at each end of the range span. The measuring slidewire may then be positioned to provide the best overall accuracy throughout the span. To adjust this slidewire, loosen the two screws securing the slidewire molding to the casting, rotate the molding, and then tighten the screws.

EMF POTENTIOMETER INSTRUMENT

If the Speedomax W instrument is used for millivolt measurements and no automatic reference junction compensation is employed, calibration is checked by direct comparison with an applied reference emf obtained from a reference potentiometer. If possible, a high-precision instrument, such as the Leeds & Northrup Type K-3 Potentiometer should be used as the reference standard. Otherwise, a portable potentiometer such as the Leeds & Northrup 8686 or No. 8662 is usually adequate. Proceed as follows:

(1) Disconnect the usual input leads and use copper wire to connect the emf terminals of the reference potentiometer to the Speedomax W input terminals. Polarities should correspond.

(2) Standardize the current of the reference potentiometer.

(3) Short-circuit or clamp the galvanometer of the reference potentiometer to eliminate spurious voltages which would be produced by motion of the galvanometer coil.

(4) Set the reference potentiometer to the emf value at which it is desired to check the Speedomax W calibration. The Speedomax W reading should correspond to the reference potentiometer setting within ±0.3% of scale span.

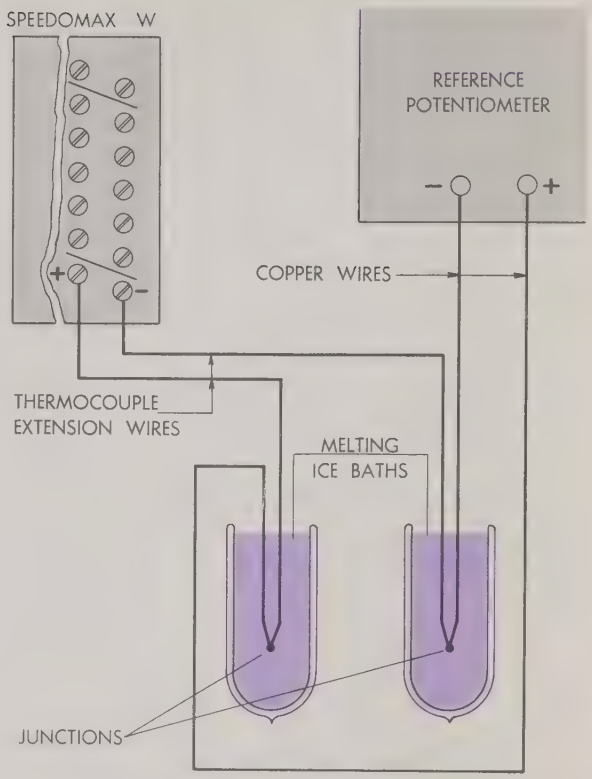


Fig. H3—Connections for calibrating thermocouple potentiometer by ice bath method.

THERMOCOUPLE POTENTIOMETER INSTRUMENT

All Speedomax W instruments for use with thermocouples are calibrated to conform to the temperature-emf values in "077989 Conversion Tables for Thermocouples" which, for iron-constantan couples, include the new tables recently derived by the National Bureau of Standards and adopted by the Scientific Apparatus Makers of America.

Deviations between the new tables and those that have been used by Leeds & Northrup Company for many years are small. However, when checking the calibration of Speedomax W instruments, use the new temperature-emf tables. A copy of the latest issue of booklet 077989 will be supplied upon request.

The procedure for checking calibration of a thermocouple potentiometer instrument is similar to

that for an emf instrument, in that a potentiometer is used as the reference emf source. It differs however, in that thermal emf's generated at junctions of copper wires and thermocouple extension wires must be taken into account. Either of two methods may be used in making the check.

Ice Bath Method—In this method, the reference potentiometer is connected to the Speedomax W in the manner shown in Fig. H3. The junctions formed at the connections of copper and extension wires are held at 32 F (0 C). In effect, this circuit constitutes a thermocouple with its measuring junction at 32 F, in series with the emf of the reference potentiometer. Such a thermocouple has zero output when referred to an emf vs. temperature conversion table whose reference temperature is 32 F. Thus the effective temperature input applied to the instrument is equal to the temperature equivalent of the reference potentiometer setting as obtained from the same conversion tables.

Proceed as follows:

(1) Use the same type of extension wires as employed with the thermocouple normally connected to the Speedomax W. Connect these wires at the instrument terminal board in the usual manner, i.e., observe polarity.

(2) Use well-compacted melting ice baths for maintaining the temperature of the copper-to-extension wire junctions. It is also permissible to use a single ice bath, provided the junctions are electrically insulated with a coating of paraffin.

(3) Immerse the junctions at least four inches in the ice baths and allow time for them to reach ice bath temperature.

(4) Standardize the current of the reference potentiometer.

(5) Short-circuit or clamp the galvanometer of the reference potentiometer to eliminate spurious voltages which would be produced by motion of the galvanometer coil.

(6) Set the reference potentiometer to the emf equivalent of the temperature at which it is desired to check the Speedomax calibration. Use the emf vs. temperature conversion table for the type of thermocouple normally employed with the instrument—reference temperature of the tables must be 32 F (0 C). The Speedomax W reading should be correct within ±0.3% of scale span.

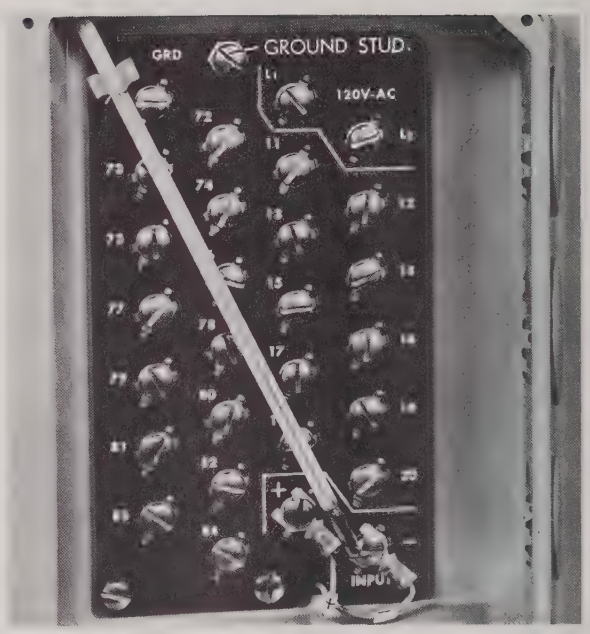


Fig. H4—Use of thermometer in field calibration of thermocouple potentiometer instrument. Leadwires from reference potentiometer connect to (+) and (—) terminals.

Field Method—Under field conditions, this method is more practical than the foregoing one. As indicated by Fig. H4, the reference potentiometer is connected to extension wire terminals at the Speedomax terminal board. In effect, this circuit constitutes a thermocouple with its measuring junction at the range card temperature, in series with the emf of the reference potentiometer. The emf equivalent of this thermocouple must be taken into account when setting the reference potentiometer to correspond to a given temperature check point.

Proceed as follows:

(1) Disconnect the measuring thermocouple leads from the terminal board.

(2) Connect the EMF leads of the portable potentiometer in place of the thermocouple leads disconnected, observing polarity.

(3) Using a calibrated mercury thermometer, the range of which is somewhat higher than ambient, measure the temperature at the terminal board where the copper wires from the portable potentiometer connect to the measuring circuit (range card) extension leadwires. Use a piece of masking or similar tape to hold the thermometer in place. See Fig. H4.

(4) Allow sufficient time for the temperature to stabilize by checking the thermometer reading periodically until successive readings indicate a stable temperature. Note this temperature reading.

(5) From the emf vs. temperature conversion tables for the type of thermocouple normally used with the Speedomax W instrument, determine the emf which corresponds to the stable reading of the mercury thermometer. From the same tables determine the emf equivalent of the temperature at which it is desired to check the Speedomax W calibration. The algebraic difference between these two emf's is the required reference potentiometer setting.

(6) Set the reference potentiometer to the value determined in (5). The Speedomax W reading should be correct within ±0.3% of scale span.

BRIDGE INSTRUMENTS

A special checking resistor may be purchased from L&N to calibrate a bridge type instrument. This precision resistor permits a rapid calibration check at one point of the instrument scale. To make the check, disconnect the primary element at the terminal board and connect the checking resistor in its place. The instrument reading should correspond to that specified on the checking resistor within ±0.3% of scale span.

It is also possible to check the instrument calibration at one or more points with resistance standards or other high precision reference resistors. Temporarily disconnect the primary element at the terminal board and connect the reference resistance in its place. Use three leads just as in the original connections, being careful that the leads connecting to terminals A and B are of equal resistance.

If the instrument reads resistance directly, adjust the reference standard to the value at which the check is to be made. Otherwise, set the reference standard to the resistance equivalent of the desired check point (use the proper conversion tables for the primary element normally employed with the instrument). The instrument reading should be correct within ±0.3% of scale span.

PART II—SERVICING AND TROUBLESHOOTING . . . . .

Section J—LOCATING TROUBLE

In some cases of faulty instrument operation, the source of trouble will be immediately apparent. In others, this will not be the case since a given symptom may often be due to any one of several causes. In locating and eliminating such faults, two methods are recommended:

(1) When trouble arises, a number of simple preliminary checks, listed later in this section, should be made before proceeding with more elaborate tests. These simple checks, which can be performed without disturbing any components of the system, are designed to detect or correct those troubles most likely to occur. They include replacement of components most likely to fail, such as tubes and electrolytic capacitors.

(2) If the trouble is not located or remedied by the simple preliminary checks, a series of tests, described later in this section, can be used to isolate the fault to one of the major sections of the system. When this is done, the faulty section can then be checked systematically to locate the particular component causing trouble.

INTERFERENCE

A special class of instrument troubles may arise from the introduction of spurious electrical signals (interference) into the amplifier. Such signals are ordinarily due to special characteristics of the installation, rather than to faults in the instrument itself. Since interference signals may enter the circuits in various ways and may not be directly detectable with ordinary measuring equipment, the elimination of interference effects is often complicated. The discussion which follows is intended to present a practical approach to the recognition and correction of some common interference problems.

Interference Effects—From the point of view of instrument performance, interference signals fall into two groups: (1) signals which produce balancing motor torque and thus cause a shift in instrument calibration; (2) signals which do not produce motor torque but which appear as noise in the amplifier signal channel, overloading the amplifier and causing sluggish operation and excessive dead band. Both types of interference may exist simultaneously, resulting in a combination of these effects. In addition, if the interference source is variable or intermittent, the adverse effects will also be of an erratic nature.

Note: This discussion concerns only those interference effects arising from the conditions of the instrument installation—not those due to faulty components within the instrument itself. It should be noted, however, that the types of faulty performance described above may be caused by failure of the tubes, filter capacitors, or other amplifier parts. Thus, if such symptoms are observed, the amplifier should be eliminated as a source of trouble before any further steps are taken. This is most conveniently done by replacing the amplifier with one known to be good and observing whether the interference effects are eliminated. If a spare amplifier is not available, it is usually sufficient to replace all amplifier plug-in components with parts known to be good.

Types of Interference—Interference can be classified according to the way it enters the instrument circuit. Most interference enters through the low level input (primary element) circuits. Two cases can be distinguished, as follows:

Transverse Interference—This type develops across the primary element leads and enters the instrument circuit in the same manner as the quantity being measured. Transverse interference is seldom a serious problem with Speedomax W instruments because the input filter (described in Section L) is designed to attenuate a-c voltages developed across the input leads. Transverse d-c interference, which may be caused by thermal emf's, can usually be prevented by avoiding the use of dissimilar metals in the connections to the primary element.

Longitudinal Interference—This type of interference develops between the primary element circuit and ground. As described in Section L, the 4-*uf* input circuit capacitor minimizes the effects of a-c longitudinal interference. However, where large voltages exist between input circuits and ground, some interference may enter and adversely affect performance.

Most troublesome interference is of the longitudinal a-c type and is attributable to (1) primary element and instrument case at different a-c ground potentials, or (2) primary element connected to a-c voltage or current source. Methods of dealing with such interference will be described.

Interference can also originate in the 120-v a-c supply to the instrument. This condition is particularly likely when the power line is ungrounded or is at a different ground potential than the instrument case or primary element. Interference entering the system from the power supply is indistinguishable in its effects from that entering through the primary element circuit.

Eliminating Interference—If the instrument exhibits the faulty performance effects described above and the amplifier has been eliminated as a source of trouble, it can be assumed that faulty operation is due to interference resulting from characteristics of the application. In this instance proceed as follows:

(1) Change the amplifier grounding connection as instructed in Section B, if this has not already been done. This simple change, which places the primary element and the amplifier chassis at a common potential, will remedy most interference troubles. If interference symptoms persist, proceed according to the applicable step below.

(2) If primary element is grounded: Leave the amplifier chassis ungrounded and connected to the primary element circuit as instructed in Section B. Then connect the instrument case, i. e., using the ground stud (GRD) beside the L_1 terminal, and the L_2 power supply terminal to the same ground point as the primary element. A separate insulated grounding wire should be used for making this connection. Note that if the 120-v power supply is ungrounded, an isolating transformer must be used as instructed in Section A.

(3) If primary element has a potential with respect to ground because of resistance coupling (e.g., temperature measurements in molten salt furnaces) or capactive coupling (e. g., transformer or stator temperature measurements):

Connect an isolating transformer in the 120-v a-c power supply to the instrument—this will be required regardless of whether or not the power line is grounded.

Remove both wires from the input circuit capacitor, Fig. B5. Solder these wires together with a third insulated wire, such that the insulated wire extends the disconnected leads to the L_2 terminal on the terminal board. Then connect the insulated wire to the L_2 terminal. Connection to L_2 may be made on either the screw side or pin side, whichever is more convenient. If made on the pin side, be sure the joint is properly soldered. Finally, tape the point where the three leads were spliced together.

PRELIMINARY CHECKS

Before proceeding with the more complicated isolation tests, follow the simple checking and replacement procedure given in Table J1. These steps will rapidly locate or remedy the great majority of instrument faults.

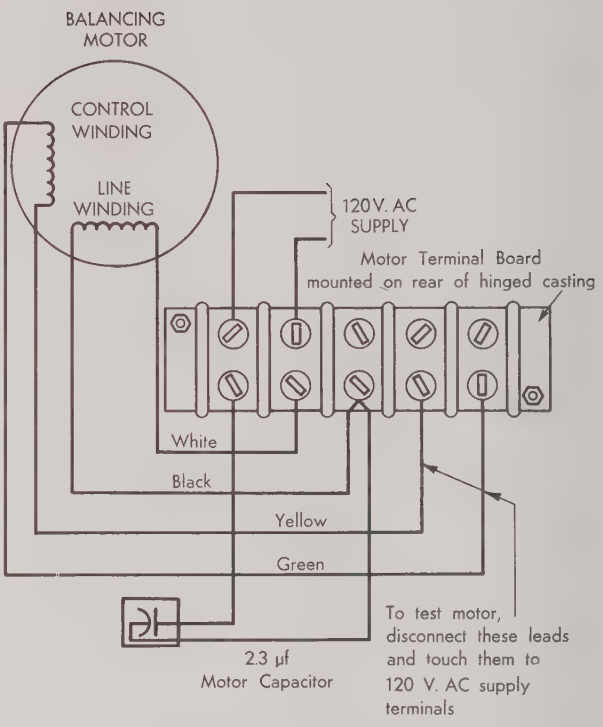


Fig. J1—Balancing motor connections.

If spare tubes and plug-in capacitors are not available, these parts can be tested rather than replaced as instructed in the table. Section K describes capacitor testing. In all cases however, replacement is preferable since it is both faster and more reliable. If more than one Speedomax W instrument is available, it is advisable to temporarily substitute parts from a properly operating instrument for those in the faulty instrument.

ISOLATION TESTS

If the trouble has not been located or corrected by simple preliminary checks, the tests given here will isolate it to one of the three major sections of the instrument: (1) the measuring circuit, (2) the amplifier, or (3) the balancing motor circuit.

Balancing Motor Test—The balancing motor can be tested simply by disconnecting the control winding leads and placing them across the line terminals of the motor terminal board as indicated in Fig. J1 (but first check that line voltage is present at the line terminals). The motor should run easily in one direction. Reversing the control winding leads should cause the motor to run in the opposite direction.

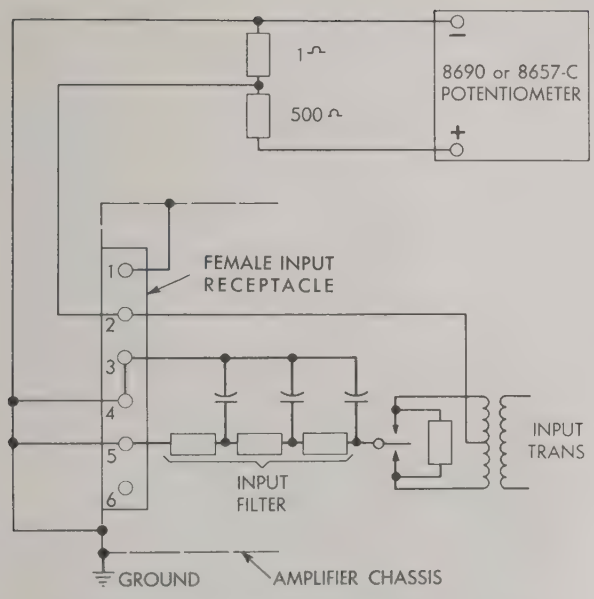


Fig. J2—Use of portable potentiometer with voltage divider as d-c test voltage source.

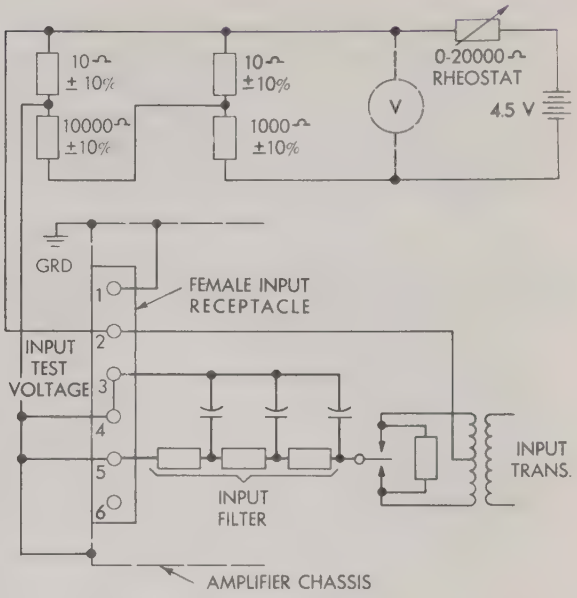


Fig. J3—Use of voltage divider network as d-c test voltage source.

If the motor runs as stated, the trouble is in the amplifier or measuring circuits. If it does not, either the motor or the 2.3-*uf* motor capacitor—located on the rear of the hinged casting—is at fault. Disconnect the capacitor and test it as instructed in Section K. Check the continuity of the motor windings. Resistance between windings and between each winding and ground should be infinite. Open- or short-circuited motors must be replaced.

Amplifier Test—Although the following test involves both the amplifier and balancing motor, it is effectively a test of the amplifier only since the motor is assumed to have been checked as described above.

A known voltage, adjustable in the range 2-50 microvolts (approximately) is required to make the test. Two suitable voltage sources are suggested.

Portable Potentiometer—The most convenient source of a known and adjustable test voltage is a portable potentiometer. The output of such a potentiometer, when loaded with a high resistance (several hundred ohms or more) is equal to the potentiometer reading. Since portable potentiometers commonly have ranges of several millivolts, a voltage dividing circuit, such as is shown in Fig. J2, is usually required. Here a Leeds & Northrup No. 8690 Millivolt Potentiometer having a range of −11.0 to +101.0 mv or No. 8657-C Portable Potentiometer having ranges of 0-16 mv and 16-64 mv, is used with a 500:1 voltage divider. The voltage divider output is equal (very nearly) to the potentiometer reading multiplied by 0.002. Therefore, when using the No. 8690 Potentiometer, it is adjustable in the range of −22 to +202 μv and, when using the No. 8657-C Potentiometer, it is adjustable in the ranges of 0-32 μv and 32-128 μv. The galvanometer of the potentiometer should be clamped during tests. When it is desired to reverse the polarity of the test voltage, the connections should be reversed at the potentiometer EMF terminals.

Voltage Divider Network—If a suitable potentiometer is not available, an adjustable test voltage may be obtained with a circuit such as that of Fig. J3. In this circuit, the test voltage is equal (very nearly) to the voltage reading on the analyzer multiplied by 0.00001. A 0-20,000 ohm rheostat is used to vary the voltage across the analyzer in the range 0.2 volt to 4.5 volts (approximately), thereby varying the test voltage from 2 to 45 microvolts (approximately). Note that the analyzer is in parallel with a relatively low resistance (1010 ohms) and therefore has only negligible effect on the test voltage. This

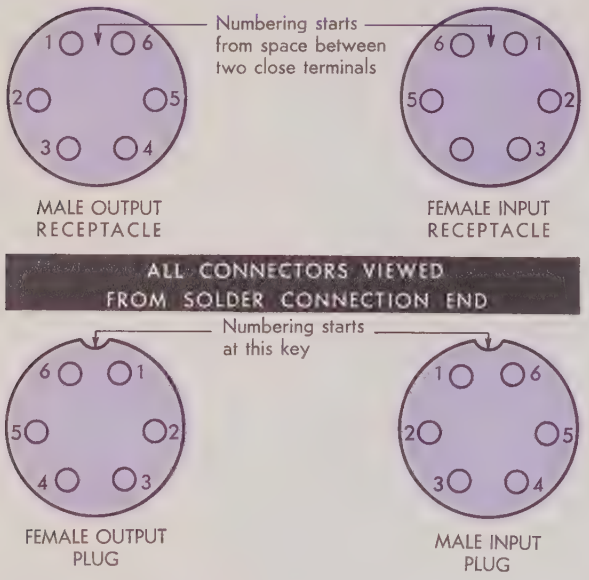

Numbering starts from space between two close terminals
MALE OUTPUT RECEPTACLE
FEMALE INPUT RECEPTACLE
ALL CONNECTORS VIEWED FROM SOLDER CONNECTION END
Numbering starts at this key
FEMALE OUTPUT PLUG
MALE INPUT PLUG

Fig. J4—Numbering of receptacles (on amplifier chassis) and plugs.

arrangement allows the analyzer to be connected while the test voltage is adjusted to the desired value, and then to be removed so that it can be used for other measurements, if required. To reverse the polarity of the test voltage, reverse the connections to the battery.

Test Procedure—The amplifier need not be removed from the instrument. With the amplifier switch turned off, pull out the amplifier input (lower) plug and connect the test input source to the amplifier as shown in Fig. J2 or J3. Cinch Mfg. Co. No. M61 male plug is suitable for connection. Note that while there are no numbers marked on either receptacles or plugs, a numbering system is assigned as shown in Fig. J4. This system is similar to that used for vacuum tube sockets, i. e., female connectors are numbered clockwise, as viewed from the solder connection end.

When connecting the test source, it is important to connect one side of the source to the amplifier chassis as shown in Figs. J2 and J3. Also, as illustrated, the chassis should be connected to the grounded instrument case or frame.

Adjust the amplifier for maximum gain during the test by turning the gain control to its clockwise limit.

Snap the amplifier switch on and adjust the test source until the balancing motor just stops running in one direction, but not against the end of the scale. Note the magnitude of the test voltage required for this condition. Then adjust the source to cause the motor to just stop running in the opposite direction (not against the end of the scale), and again note the test voltage.

The algebraic difference betwen the two voltages noted above is the amplifier dead band. Its magnitude should not be greater than 20 microvolts.

The amplifier zero offset is defined as one half the algebraic sum of the two voltages noted above. Its magnitude should not exceed 15 microvolts.

Note: For zero offset requirements on the No. 101042 Fail-Safe amplifier, refer to the appendix.

If the zero offset and dead band are within the stated limits, the amplifier and balancing motor are operating properly and the trouble is in the measuring circuit. If the specified conditions are not met, proceed with amplifier troubleshooting as instructed in Section K.

TROUBLESHOOTING MEASURING CIRCUIT

If preceding tests have isolated the fault to the measuring circuit, proceed with troubleshooting according to the following steps:

(1) On potentiometer-type instruments, measure the d-c voltage across the potentiometer circuit, accessible at the output terminals of the regulated power supply. This should be approximately 1 volt.

(2) Check continuity through the measuring slidewire and its contacts. On instruments having one or more compensator rheostats, also check continuity through these parts.

(3) Test the 4-μf input circuit capacitor or substitute another for it, if this has not already been done.

(4) Remove the range card from the instrument and substitute a spare card of the same type. If this restores correct operation, the faulty range card must be replaced.

SYMPTOM	RECOMMENDED CHECKS and REPLACEMENTS
1 Instrument is completely inoperative including chart motor or motors.	Replace fuse in amplifier. If new fuse blows immediately, refer to 3 below. If fuse is good, check line voltage across terminals L_1 and L_2 of main terminal board.
2 Line supply and fuse are good, but there is no balancing action.	Examine range card connector for contacts bent away from printed circuit board. Also check to see that all connections to motor terminal block, and main terminal board are tight. Replace all tubes and electrolytic plug-in capacitors with new ones. If this restores operation, the old parts can be replaced one by one, thus locating the faulty part.
3 Fuse blows when replaced.	Disconnect and tape line leads from terminals K and W of motor terminal board and then replace fuse. If fuse still blows, trouble is in amplifier (see Section K). If fuse does not blow, trouble is in one of the motors. Test for short circuits between all motor leads and instrument case.
4 Instrument response is sluggish and/or dead band is excessive (see Section H).	Replace capacitors and tubes as in 2 above. With instrument turned off, manually rotate balancing motor shaft (a screwdriver slot is provided in motor worm). The shaft should turn easily for all positions of the instrument pointer and there should be no binding or backlash in mechanical system.
5 Instrument operates erratically, oscillates, or overshoots balance point.	Check and adjust amplifier gain and damping (Section B). Check all connections to range card (including range card connector for bent contacts), terminal boards, and primary element.
6 Operation appears normal but instrument reading is in error.	Check regulated power supply output voltage using a reference potentiometer. Check calibration of primary element. Check instrument calibration (see Section H).
7 The fault cannot be corrected or located by any of the preceding steps of this table.	Replace the amplifier with one known to be good. If this eliminates the trouble, service the faulty amplifier as instructed in Section K.

Table J1

Section K—AMPLIFIER TROUBLESHOOTING

This section describes the testing and servicing procedures to be followed when the checks of Section J indicate amplifier trouble.

TEST EQUIPMENT

A volt-ohmmeter analyzer is required for checking a-c and d-c voltages and resistance values. The analyzer should have 20,000-ohms-per-volt impedance on the d-c voltage ranges and 1000-ohms-per-volt impedance on the a-c voltage ranges, since the voltages given in this book are those to be obtained with a meter having these impedances. The Simpson Model 260 Analyzer has the required characteristics. If a lower impedance voltmeter is used in measuring voltages across high resistance circuits, lower readings must be expected, and conversely.

Plugs should be available to allow easy connection to the amplifier input and output receptacles. Cinch Mfg. Co. No. M-61 male plug is suitable for connection to the input receptacle, while No. F-60 female plug fits the output receptacle.

GENERAL TEST INFORMATION

Preliminary Checks—Do not proceed with the tests of this section until the simple checks previously described have been carried out. It is particularly important to replace all tubes and plug-in capacitors with parts known to be good. Tubes and electrolytic capacitors are not considered as possible sources of trouble in this section.

Circuit Variations—All voltages and resistances listed in this section are those to be obtained with an amplifier having the circuits shown in Figs. K2, K4, and K6. When testing, make allowances for any discrepancies between these circuits and the actual circuit of the amplifier under test.

Amplifier Types—Table K1 lists the general characteristics of amplifiers used in Speedomax W instruments. All are covered in this section except the 101042 and 101043 which are covered in the appendix.

Capacitor Testing—Capacitors of high value (0.1 μf and larger) are to be tested with the analyzer set to its highest ohms range. When taking resistance readings across a capacitor or in any circuit where a capacitor is across the analyzer or in series with the circuit and the analyzer, the needle of the analyzer should deflect when first connected and then return to the value of resistance which may be involved in the circuit. This deflection indicates the capacitor is good and will take a charge. If the deflection does not occur, it will indicate that the capacitor is open-circuited and should be replaced. If the analyzer needle deflects and remains below the value of any parallel resistive components, the capacitor is short-circuited or is leaky and should be replaced.

Fig. K1—Location of converter adjustment hole. Other hole is diametrically opposite hole shown.

Note: Some leakage is to be expected on electrolytic capacitors. Also on electrolytic capacitors, the proper polarity must be observed since incorrect connections of the ohmmeter will show a low resistance reading even on a good capacitor.

Replacing Components—When faulty parts are replaced, the new parts and wiring should conform to the original arrangement. When resoldering, use as little solder as possible, but be sure that a satisfactory connection is made.

Test Procedure—It is suggested that the various steps in amplifier troubleshooting be performed in the sequence given in Tables K2, K3 and K4 since these tables are arranged so that components most likely to fail are tested first.

When making voltage checks, the amplifier input plug should be removed. Where not instructed otherwise, the amplifier ON-OFF switch is to be in the ON position, and the gain control turned to its counterclockwise setting. The amplifier may be powered from the instrument by means of an extension cable, or it can be bench-tested by connecting the a-c line directly to pins 1 and 6 of the output receptacle. In all tests, the balancing motor control winding is assumed to be disconnected from the amplifier.

The line voltage is to be 120 v a-c and the tolerances on all voltages and resistances given in the table are ±20% unless otherwise specified.

Converter Adjustment — Incorrect converter closure times may result in excessive amplifier offset or dead band, or may cause overshoot and cycling. If converter closure times are not within the limits specified in Step 5 (c) of the table and a spare converter is available, use the spare as a replacement. Return the defective converter to L&N if its warranty period is still in effect. If no spare is available, the converter may be adjusted, for emergency use only, in accordance with the following procedure.

Use a sharp instrument to punch two holes in the metal label of the converter at the points indicated in Fig. K1. With the analyzer connected to measure contact closure, as in Step 5 (c) of the table, use a #6 hex socket setscrew wrench to turn the adjusting screws (see converter illustration, Section M) until closure time is 42% for each set of contacts. The front adjustment (facing the viewer in Fig. K1) controls closure time between pins 2 and 3. Turning the adjusting screw clockwise decreases closure time, and conversely.

Important: After adjusting the converter, use a piece of non-magnetic metallic tape to seal the holes in the case. This is essential since the entrance of even small amounts of dust may render the converter unusable.

AMPLIFIER*	DAMPING RESISTANCE**	FREQUENCY (cps)	APPLICATION	FEATURES
101040 101041	2500 ohms	60 50	For ranges above 5 mv.	———
101042 101043	2500 ohms	60 50	Same as above but for fail-safe operation.	Fail-safe circuitry
101112 101113	2500 ohms	60 50	For ranges of 5 mv or less.	High gain. Provision for remote adjustment of amplifier gain.
101120 101121	25000 ohms	60 50		

* All amplifiers listed are for measuring d-c potentiometer and bridge type circuits only; all operate on 120v a-c.

** Maximum source impedance for optimum performance.

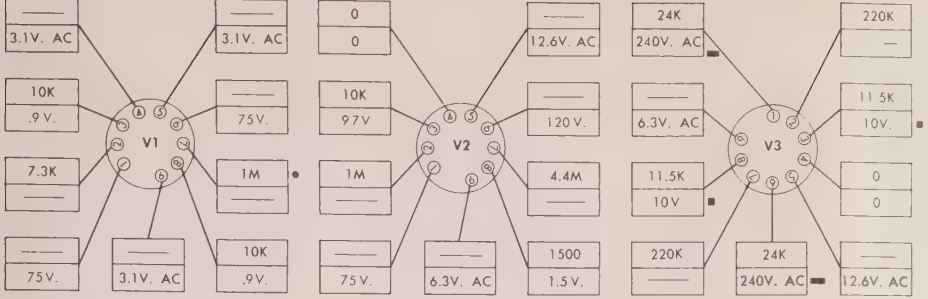
Table K1—General characteristics of Speedomax W amplifiers.

STEP	TEST INSTRUCTIONS	NORMAL INDICATION	PROBABLE CAUSE OF ABNORMAL INDICATION
1 Power Transformer Test	Measure a-c voltage between: (a) Pins 1 and 6 of V3 (b) Pins 4 and 5 of V3 (c) Pins 4 and 5 of V2 (d) Pins 4 and 9 of V1 (e) Chassis and pin 4 of V1 (f) Chassis and pin 5 of V3 (g) Chassis and negative end of rectifier Y1	Transformer voltages within ±10%: (a) 480 v a-c (b) 12.6 v a-c (c) 12.6 v a-c (d) 6.3 v a-c (e) 3.2 v a-c (f) 12.6 v a-c (g) 250 v a-c	Faulty power transformer T2 Faulty switch S1
2 B+ Voltage Test	Measure d-c voltage from chassis to: (a) Positive end of rectifier Y1 (b) C14 (c) C13 (d) C6	(a) 265 v d-c (b) 260 v d-c (c) 220 v d-c (d) 190 v d-c	(a) Y1 faulty (b) R7 open (c) R6 open (d) R5 open
3 Plate Voltage Test	Measure d-c voltage from chassis to: (a) Pin 1 of V1 (b) Pin 6 of V1 (c) Pin 1 of V2 (d) Pin 6 of V2	(a) 75 v d-c (b) 75 v d-c (c) 75 v d-c (d) 120 v d-c	(a) R9 or R16 open (b) R10 or R17 open (c) R11 or R19 open (d) R12 or R22 open
4 Bias Voltage Test	Remove V1 and measure d-c voltage from chassis to: Pin 8 of V3	10 v d-c	R13, R24, or R22 open
5 (a) Converter Drive Voltage Test	Leave converter top plug connected. Measure converter a-c driving voltage at converter cable connections under chassis.	19±3 v a-c	Resistor R8 open Converter drive coil open or shorted to case Faulty power transformer
5 (b) Converter Ground Test	With amplifier switch off, remove converter and disconnect top plug. Measure resistance (highest ohms range) between: (a) Converter case and pin 3 of base (b) Converter case and pin in top receptacle (c) Converter case and pin 6 of base	(a) Resistance infinite (b) Resistance infinite (c) Zero resistance	(a) Converter contact grounded to case (b) Converter drive coil grounded to case (c) Open ground connection
5 (c) Converter Closure Time Test	With amplifier switch ON, remove converter from socket but leave top plug connected. Connect analyzer (ohms x 100 range) between: (a) Pins 2 and 3 of converter base (b) Pins 3 and 4 of converter base NOTE: Converter must be vertical and analyzer horizontal.	(a) and (b): Reading between 35 and 55 on 0-100 d-c volts scale (Reading is equal to percentage of time the contacts are closed.)	Incorrect driving voltage Converter out of adjustment (see instructions on adjusting)
6 Motor Capacitor Test	With power off, disconnect one lead of capacitor C16. Measure resistance of C16 (highest ohms range)	Resistance infinite	Faulty motor tuning capacitor C16

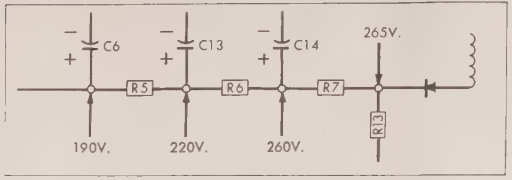
Table K2—101040 or 101041 Amplifier testing procedure (table continued on following page).

STEP	TEST INSTRUCTIONS	NORMAL INDICATION	PROBABLE CAUSE OF ABNORMAL INDICATION
7 Gain Control Test	With power off, measure resistance between: (a) Chassis and pin 7 of V1 (b) End terminals of gain control R15	 (a) Resistance varies smoothly from 0 to 1 megohm as gain control knob is turned clockwise (b) 1 megohm	 Gain control R15 faulty
8 Cathode Resistor Tests	With power off, measure resistance between chassis and: (a) Pin 3 of V1 (b) Pin 8 of V1 (c) Pin 3 of V2 (d) Pin 8 of V2	 (a) 10,000 ohms (b) 10,000 ohms (c) 10,000 ohms (d) 1,500 ohms	 (a) R16 open (b) R17 open (c) R19 open (d) R22 open
9 Input Transformer Tests	With power off, remove converter. Measure resistance between: (a) Pins 2 and 4 of converter socket (b) Chassis and pin 2 of V1 (c) Chassis and pin 2 of converter socket	 (a) 480±20 ohms (b) 7300 ohms (c) Infinite	 (a) Resistor R4 or input transformer primary open. (Resistance of primary alone should be 550 ohms.) (b) Capacitor C4 shorted or input transformer secondary open (c) Short circuit between transformer windings
10 Grid Resistor Test	With power off, measure resistance between chassis and: (a) Pin 2 of V2 (b) Pin 7 of V2 (c) Pin 2 or 7 of V3	 (a) 1 megohm (b) 4.4 megohm (c) .22 megohm	 (a) R18 open (b) R21, R20 open (c) R23 open
11 (a) Coupling Capacitor Tests	Measure d-c voltage between chassis and: (a) Pin 7 of V1 (b) Pin 2 of V2 (c) Pin 7 of V2 (d) Pin 2 of V3	 Zero d-c voltage	 (a) C9 shorted (b) C10 shorted (c) C11 shorted (d) C12 shorted
11 (b) Coupling Capacitor Tests	Connect analyzer (a-c range) between chassis and pin 2 of V3. Clip one end of an insulated test lead to pin 4 of V1. Touch other end of test lead to: (a) Pin 7 of V2 (b) Pin 2 of V2 (c) Pin 7 of V1 (d) Pin 1 of V1 (turn gain control to clockwise limit)	 A change in analyzer reading upon touching each pin	 (a) C12 open (b) C11 open (c) C10 open (d) C9 open
12 Filter Capacitor Test	Remove amplifier input plug. Measure resistance between pins 3 and 5 of input receptable (highest ohms range)	Reading is infinite after initial kick	Shorted filter, capacitor C1, C2, or C3

Table K2 (concluded).



● gain setting maximum
■ measured with V3 removed
▬ measured with respect to pin 3 or 8 of V3



NOTES

1. In socket chart, lower section of each block gives voltage, upper section of each block gives resistance. Voltages and resistances are measured to chassis except as indicated.

2. Voltages are d-c except as indicated. These are average values to be obtained with 120 v a-c line voltage applied to amplifier, and gain control set to counterclockwise limit.

3. Measurements are made with balancing motor control winding disconnected from amplifier.

4. Abbreviations as follows: M = megohm, K = thousand ohms

RESISTORS

		L&N Part No.
R1	5600Ω	11-1-0-53
R2	2000Ω	11-4-0-95
R3	2000Ω	11-4-0-95
R4	10K	11-1-0-56
R5	100K	11-1-0-68
R6	100K	11-1-0-68
R7	10K	11-1-0-56
R8	2700Ω 3W	011623
R9	1 Meg	11-1-0-80
R10	1 Meg	11-1-0-80
R11	1 Meg	11-1-0-80
R12	1 Meg	11-1-0-80
R13	270K	11-1-0-73
R14	22K	11-1-0-60
R15	1 Meg	013138
R16	10K	11-1-0-56
R17	10K	11-1-0-56
R18	1 Meg	11-1-0-80
R19	10K	11-1-0-56
R20	2.2 Meg	11-1-0-84
R21	2.2 Meg	11-1-0-84
R22	1500Ω	11-1-0-46
R23	220K	11-1-0-72
R24	10K	11-1-0-56

CAPACITORS

C1	8µf	5vDC	R-820-L
C2	8µf	5vDC	
C3	8µf	5vDC	
▲C4	.001µf	500vDC	023125
▲C5	.001µf	500vDC	
▲C6	4µf	300vDC	
▲C7	25µf	2vDC	023123
▲C8	25µf	2vDC	
C9	.022µf	400vDC	23-3-0-20
C10	.022µf	400vDC	23-3-0-20
C11	.022µf	400vDC	23-3-0-20
C12	.1µf	400vDC	23-3-0-8
▲C13	4µf	300vDC	
▲C14	4µf	300vDC	023122
▲C15	25µf	10vDC	
C16	1µf	130vAC	023124

MISCELLANEOUS

T1	Input Transformer	Std. 21178-39
T2	Power Transformer	019183
▲V1	12AX7	22-1-0-6
▲V2	12AX7	22-1-0-6
▲V3	12BH7	022062
▲X1	Converter 60 cycle	354156*
▲X1	Converter 50 cycle	354169**
X2	Converter Cable	037253
▲F1	1 amp Slo-Blo	014049
S1	Line Switch	032197
Y1	Rectifier	057016
	Socket for V1 & V2	40-1-0-8
	Socket for V3	40-1-0-4
	Output Receptacle	Std. 3246-176
	Input Receptacle	Std. 3246-174

*For 101040 Amplifier **For 101041 Amplifier

▲Recommended for spare parts stock

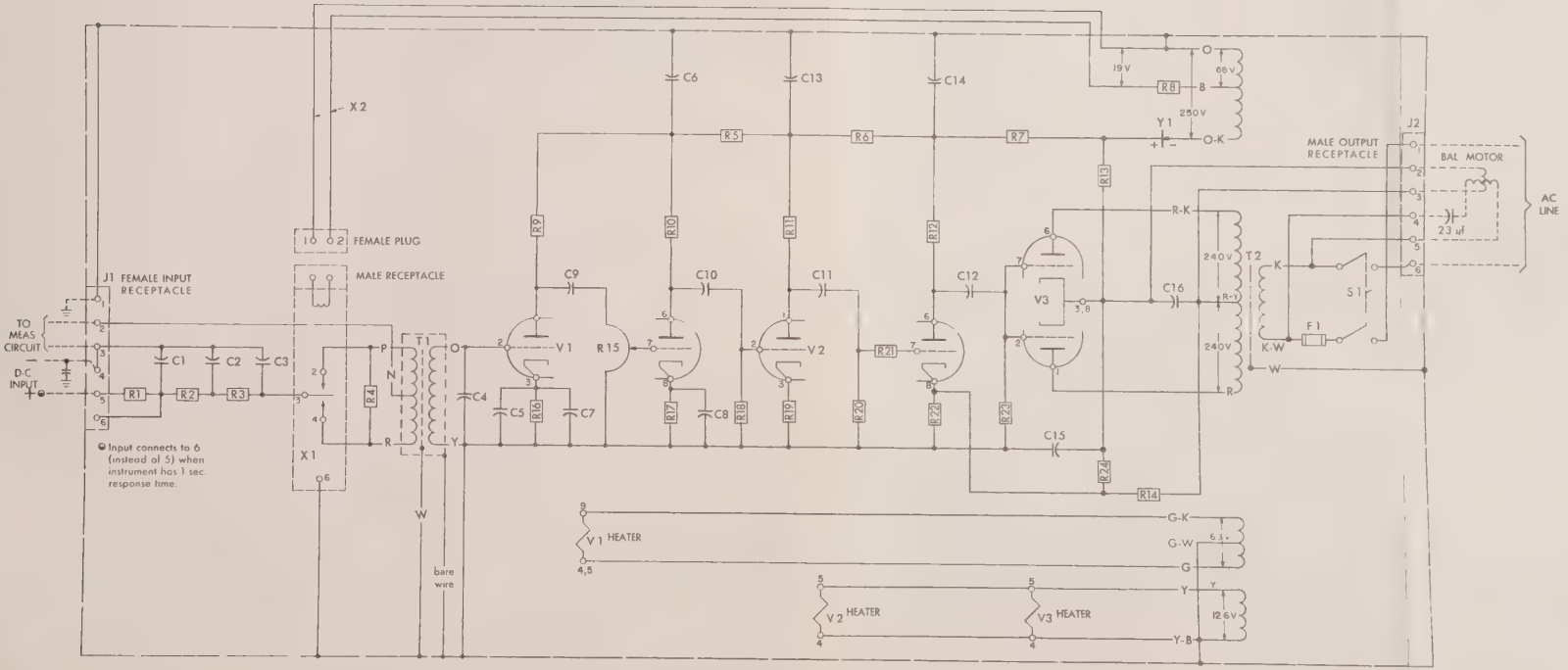
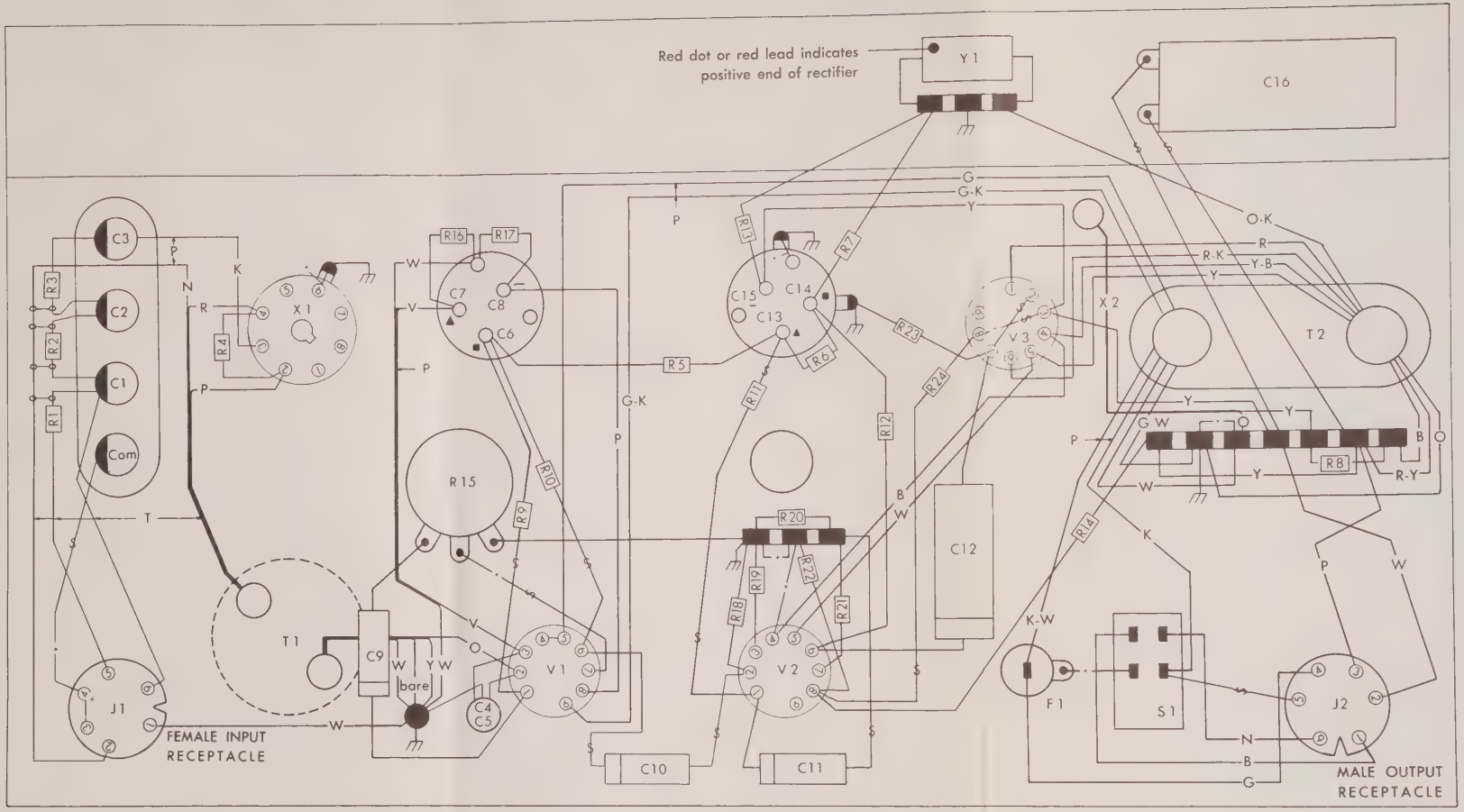


Fig. K2—Schematic of 101040 or 101041 Amplifier with test data.



NOTE

All resistors are ½ watt, with ±10% tolerance except as noted.

SYMBOLS

- indicates leads twisted around resistors
- P — indicates tightly twisted leads
- T — indicates three tightly twisted leads
- S indicates insulated tubing
- * indicates tinned wire
- indicates outside foil of paper capacitors

COLOR CODE

K — Black	Y — Yellow
W — White	A — Gray
G — Green	V — Violet
R — Red	P — Pink
B — Blue	S — Slate
N — Brown	T — Tan
O — Orange	

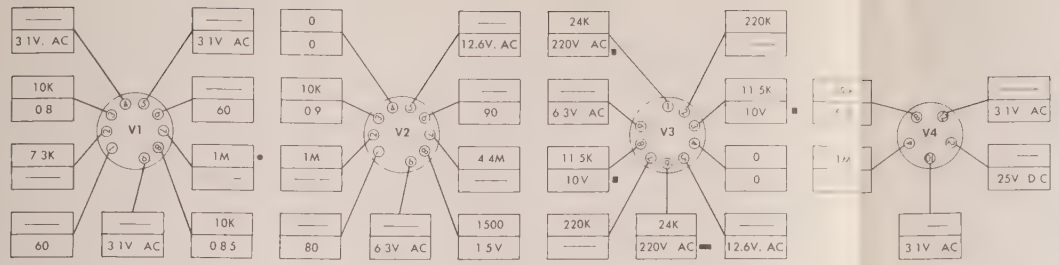
Fig. K3—Wiring diagram of 101040 or 101041 Amplifier.

STEP	TEST INSTRUCTIONS	NORMAL INDICATION	PROBABLE CAUSE OF ABNORMAL INDICATION
1 Power Transformer Test	Measure a-c voltage between: (a) Pins 1 and 6 of V3 (b) Pins 4 and 5 of V3 (c) Pins 4 and 5 of V2 (d) Pins 4 and 9 of V1 (e) Pins 10 and 12 of V4 (f) Chassis and pin 4 of V1 (g) Chassis and pin 5 of V3 (h) Chassis and negative end of rectifier Y1	Transformer voltages within ±10%: (a) 480 v a-c (b) 12.6 v a-c (c) 12.6 v a-c (d) 6.3 v a-c (e) 6.3 v a-c (f) 3.1 v a-c (g) 12.6 v a-c (h) 250 v a-c	Faulty power transformer T2 Faulty switch S1
2 B+ Voltage Test	Measure d-c voltage from chassis to: (a) Positive end of rectifier Y1 (b) C14 (c) C13 (d) C6	(a) 248 v d-c (b) 240 v d-c (c) 180 v d-c (d) 160 v d-c	(a) Y1 faulty (b) R7 open (c) R6 open (d) R5 open
3 Plate Voltage Test	Measure d-c voltage from chassis to: (a) Pin 1 of V1 (b) Pin 6 of V1 (c) Pin 1 of V2 (d) Pin 6 of V2 (e) Pin 2 of V4	(a) 60 v d-c (b) 60 v d-c (c) 80 v d-c (d) 90 v d-c (e) 25 v d-c	(a) R9 or R16 open (b) R10 or R17 open (c) R11 or R19 open (d) R12 or R22 open (e) R25 or R26 open
4 Bias Voltage Test	Remove V1 and measure d-c voltage from chassis to: Pin 8 of V3	10 v d-c	R13, R24, or R22 open
5 (a) Converter Drive Voltage Test	Leave converter top plug connected. Measure converter a-c driving voltage at converter cable connections under chassis.	19±3 v a-c	Resistor R8 open Converter drive coil open or shorted to case Faulty power transformer
5 (b) Converter Ground Test	With amplifier switch off, remove converter and disconnect top plug. Measure resistance (highest ohms range) between: (a) Converter case and pin 3 of base (b) Converter case and pin in top receptacle (c) Converter case and pin 6 of base	(a) Resistance infinite (b) Resistance infinite (c) Zero resistance	(a) Converter contact grounded to case (b) Converter drive coil grounded to case (c) Open ground connection
5 (c) Converter Closure Time Test	With amplifier switch ON, remove converter from socket but leave top plug connected. Connect analyzer (ohms x 100 range) between: (a) Pins 2 and 3 of converter base (b) Pins 3 and 4 of converter base NOTE: Converter must be vertical and analyzer horizontal.	(a) and (b): Reading between 35 and 55 on 0-100 d-c volts scale (Reading is equal to percentage of time the contacts are closed.)	Incorrect driving voltage Converter out of adjustment (see instructions on adjusting)
6 Motor Capacitor Test	With power off, disconnect one lead of capacitor C16. Measure resistance of C16 (highest ohms range)	Resistance infinite	Faulty motor tuning capacitor C16

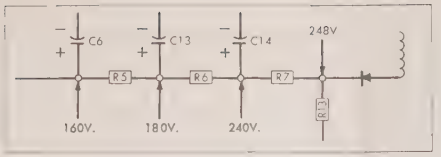
Table K3—101112 or 101113 Amplifier testing procedure (table continued on following page).

STEP	TEST INSTRUCTIONS	NORMAL INDICATION	PROBABLE CAUSE OF ABNORMAL INDICATION
7 Gain Control Test	With power off, measure resistance between: (a) Chassis and pin 7 of V1 (b) End terminals of gain control R15	(a) Resistance varies smoothly from 0 to 1 megohm as gain control knob is turned clockwise (b) 1 megohm	Gain control R15 faulty
8 Cathode Resistor Tests	With power off, measure resistance between chassis and: (a) Pin 3 of V1 (b) Pin 8 of V1 (c) Pin 3 of V2 (d) Pin 8 of V2 (e) Pin 8 of V4	 (a) 10,000 ohms (b) 10,000 ohms (c) 10,000 ohms (d) 1,500 ohms (e) 39,000 ohms	 (a) R16 open (b) R17 open (c) R19 open (d) R22 open (e) R26 open
9 Input Transformer Tests	With power off, remove converter. Measure resistance between: (a) Pins 2 and 4 of converter socket (b) Chassis and pin 2 of V1 (c) Chassis and pin 2 of converter socket	 (a) 480±20 ohms (b) 7300 ohms (c) Infinite	 (a) Resistor R4 or input transformer primary open. (Resistance of primary alone should be 550 ohms.) (b) Capacitor C4 shorted or input transformer secondary open (c) Short circuit between transformer windings
10 Grid Resistor Test	With power off, measure resistance between chassis and: (a) Pin 2 of V2 (b) Pin 7 of V2 (c) Pin 2 or 7 of V3	 (a) 1 megohm (b) 4.4 megohm (c) .22 megohm	 (a) R18 open (b) R21, R20 open (c) R23 open
11 (a) Coupling Capacitor Tests	Measure d-c voltage between chassis and: (a) Pin 7 of V1 (b) Pin 2 of V2 (c) Pin 7 of V2 (d) Pin 2 of V3 (e) Pin 4 of V4	 Zero d-c voltage	 (a) C9 shorted (b) C10 shorted (c) C11 shorted (d) C12 shorted (e) C10 shorted
11 (b) Coupling Capacitor Tests	Connect analyzer (a-c range) between chassis and pin 2 of V3. Clip one end of an insulated test lead to pin 4 of V1. Touch other end of test lead to: (a) Pin 7 of V2 (b) Pin 2 of V2 (c) Pin 4 of V4 (d) Pin 7 of V1 (e) Pin 1 of V1 (turn gain control to clockwise limit)	 A change in analyzer reading upon touching each pin	 (a) C12 open (b) C11 open (c) C17 open (d) C10 open (e) C9 open
12 Filter Capacitor Test	Remove amplifier input plug. Measure resistance between pins 3 and 5 of input receptable (highest ohms range)	Reading is infinite after initial kick	Shorted filter, capacitor C1, C2, or C3

Table K3 (concluded).



● gain setting maximum
■ measured with V3 removed
▬ measured with respect to pin 3 or 8 of V3



NOTES

1. In socket chart, lower section of each block gives voltage, upper section of each block gives resistance. Voltages and resistances are measured to chassis except as indicated.

2. Voltages are d-c except as indicated. These are average values to be obtained with 120 v a-c line voltage applied to amplifier, and gain control set to counterclockwise limit.

3. Measurements are made with balancing motor control winding disconnected from amplifier.

4. Abbreviations as follows: M = megohm, K = thousand ohms.

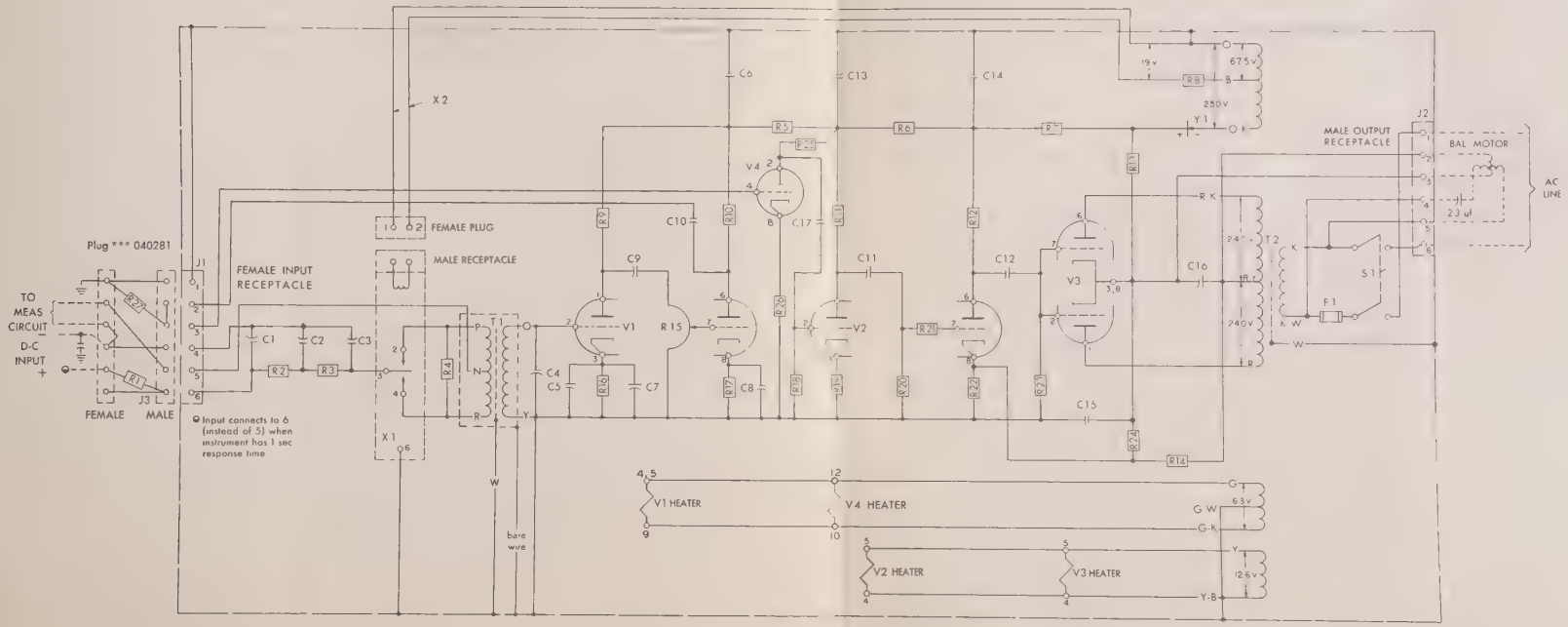


Fig. K4—Schematic of 101112 or 101113 Amplifier with test data.

RESISTORS

			L&N Part No.
***	R1	5600Ω	11-1-0-53
	R2	2000Ω	11-4-0-95
	R3	2000Ω	11-4-0-95
	R4	12K	11-1-0-57
	R5	100K	11-1-0-68
	R6	100K	11-1-0-68
	R7	10K	11-1-0-56
	R8	2700Ω 3W	011623
	R9	1 Meg	11-1-0-80
	R10	1 Meg	11-1-0-80
	R11	1 Meg	11-1-0-80
	R12	1 Meg	11-1-0-80
	R13	270K	11-1-0-73
	R14	22K	11-1-0-60
	R15	1 Meg	013138
	R16	10K	11-1-0-56
	R17	10K	11-1-0-56
	R18	1 Meg	11-1-0-80
	R19	10K	11-1-0-56
	R20	2.2 Meg	11-1-0-84
	R21	2.2 Meg	11-1-0-84
	R22	1500Ω	11-1-0-46
	R23	220K	11-1-0-72
	R24	10K	11-1-0-56
	R25	1 Meg	11-1-0-80
	R26	39K	11-1-0-63
**	R27	1 Meg	11-1-0-80

CAPACITORS

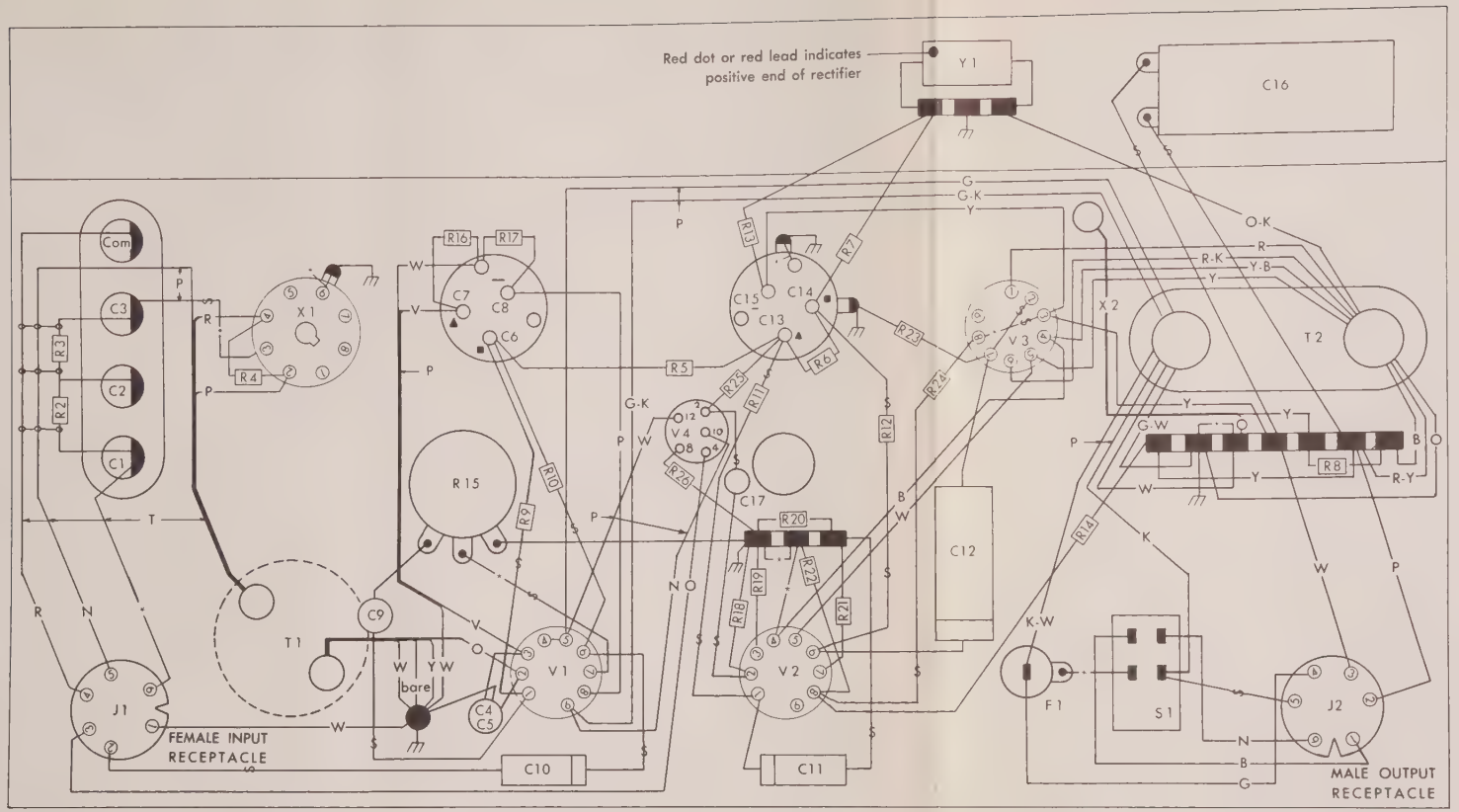
	C1	8µf	5vDC
	C2	8µf	5vDC
	C3	8µf	5vDC
▲	C4	.001µf	500vDC
▲	C5	.001µf	500vDC
▲	C6	4µf	300vDC
▲	C7	25µf	2vDC
▲	C8	25µf	2vDC
	C9	02µf	450vDC
	C10	.022µf	400vDC
	C11	.022µf	400vDC
	C12	.1µf	400vDC
▲	C13	4µf	300vDC
▲	C14	4µf	300vDC
▲	C15	25µf	10vDC
	C16	1µf	130vAC
	C17	.02µf	450vDC

	R-820-L	C1, C2, C3
	023125	C4, C5
	023123	C6, C7, C8
	023096	C9
	23-3-0-20	C10
	23-3-0-20	C11
	23-3-0-8	C12
	023122	C13, C14, C15
	023124	C16
	023096	C17

MISCELLANEOUS

	T1 Input Transformer	Std. 21178-39
	T2 Power Transformer	019183
▲	V1 12AX7	22-1-0-6
▲	V2 12AX7	22-1-0-6
▲	V3 12BH7	022062
▲	V4 7586	022007
▲	X1 Converter 60 cycle	354156*
▲	X1 Converter 50 cycle	354169**
	X2 Converter Cable	037253
▲	F1 1 amp Slo-Blo	014049
	S1 Line Switch	032197
	Y1 Rectifier	057016
	Socket for V1 & V2	40-1-0-8
	Socket for V3	40-1-0-4
	Socket for V4	040285
	Output Receptacle	Std. 3246-176
	Input Receptacle	Std. 3246-174

*For 101112 Amplifier **For 101113 Amplifier
▲ Recommended for spare parts stock
***See Note 2, other side



NOTES

1. All resistors are ½ watt, with ±10% tolerance except as noted.
2. Plug (040281) is required when remote amplifier gain control circuit is not required. Resistors R1 and R27 supplied in part 040281.

SYMBOLS

- indicates leads twisted around resistors
- P — indicates tightly twisted leads
- T — indicates three tightly twisted leads
- S indicates insulated tubing
- * indicates tinned wire
- indicates outside foil of paper capacitors

COLOR CODE

K — Black	Y — Yellow
W — White	A — Gray
G — Green	V — Violet
R — Red	P — Pink
B — Blue	S — Slate
N — Brown	T — Tan
O — Orange	

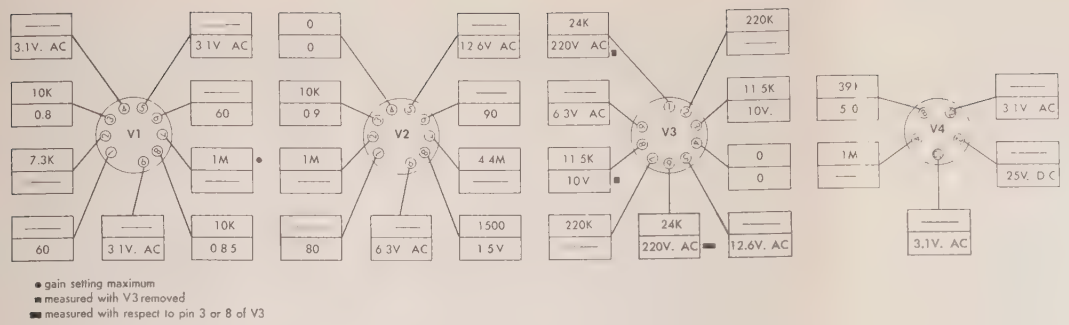
Fig. K5—Wiring diagram of 101112 or 101113 Amplifier.

STEP	TEST INSTRUCTIONS	NORMAL INDICATION	PROBABLE CAUSE OF ABNORMAL INDICATION
1 Power Transformer Test	Measure a-c voltage between: (a) Pins 1 and 6 of V3 (b) Pins 4 and 5 of V3 (c) Pins 4 and 5 of V2 (d) Pins 4 and 9 of V1 (e) Pins 10 and 12 of V4 (f) Chassis and pin 4 of V1 (g) Chassis and pin 5 of V3 (h) Chassis and negative end of rectifier Y1	Transformer voltages within ±10%: (a) 480 v a-c (b) 12.6 v a-c (c) 12.6 v a-c (d) 6.3 v a-c (e) 6.3 v a-c (f) 3.1 v a-c (g) 12.6 v a-c (h) 250 v a-c	Faulty power transformer T2 Faulty switch S1
2 B+Voltage Test	Measure d-c voltage from chassis to: (a) Positive end of rectifier Y1 (b) C14 (c) C13 (d) C6	(a) 248 v d-c (b) 240 v d-c (c) 180 v d-c (d) 160 v d-c	(a) Y1 faulty (b) R7 open (c) R6 open (d) R5 open
3 Plate Voltage Test	Measure d-c voltage from chassis to: (a) Pin 1 of V1 (b) Pin 6 of V1 (c) Pin 1 of V2 (d) Pin 6 of V2 (e) Pin 2 of V4	(a) 60 v d-c (b) 60 v d-c (c) 80 v d-c (d) 90 v d-c (e) 25 v d-c	(a) R9 or R16 open (b) R10 or R17 open (c) R11 or R19 open (d) R12 or R22 open (e) R25 or R26 open
4 Bias Voltage Test	Remove V1 and measure d-c voltage from chassis to: Pin 8 of V3	10 v d-c	R13, R24, or R22 open
5 (a) Converter Drive Voltage Test	Leave converter top plug connected. Measure converter a-c driving voltage at converter cable connections under chassis.	19±3 v a-c	Resistor R8 open Converter drive coil open or shorted to case Faulty power transformer
5 (b) Converter Ground Test	With amplifier switch off, remove converter and disconnect top plug. Measure resistance (highest ohms range) between: (a) Converter case and pin 3 of base (b) Converter case and pin in top receptacle (c) Converter case and pin 6 of base	(a) Resistance infinite (b) Resistance infinite (c) Zero resistance	(a) Converter contact grounded to case (b) Converter drive coil grounded to case (c) Open ground connection
5 (c) Converter Closure Time Test	With amplifier switch ON, remove converter from socket but leave top plug connected. Connect analyzer (ohms x 100 range) between: (a) Pins 2 and 3 of converter base (b) Pins 3 and 4 of converter base NOTE: Converter must be vertical and analyzer horizontal.	(a) and (b): Reading between 35 and 55 on 0-100 d-c volts scale (Reading is equal to percentage of time the contacts are closed.)	Incorrect driving voltage Converter out of adjustment (see instructions on adjusting)
6 Motor Capacitor Test	With power off, disconnect one lead of capacitor C16. Measure resistance of C16 (highest ohms range)	Resistance infinite	Faulty motor tuning capacitor C16

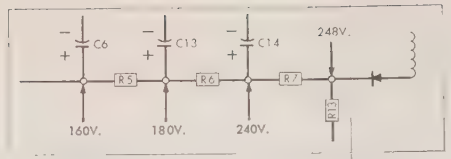
Table K4—101120 or 101121 Amplifier testing procedure (table continued on following page).

STEP	TEST INSTRUCTIONS	NORMAL INDICATION	PROBABLE CAUSE OF ABNORMAL INDICATION
7 Gain Control Test	With power off, measure resistance between: (a) Chassis and pin 7 of V1 (b) End terminals of gain control R15	(a) Resistance varies smoothly from 0 to 1 megohm as gain control knob is turned clockwise (b) 1 megohm	Gain control R15 faulty
8 Cathode Resistor Tests	With power off, measure resistance between chassis and: (a) Pin 3 of V1 (b) Pin 8 of V1 (c) Pin 3 of V2 (d) Pin 8 of V2	 (a) 10,000 ohms (b) 10,000 ohms (c) 10,000 ohms (d) 1,500 ohms	 (a) R16 open (b) R17 open (c) R19 open (d) R22 open
9 Input Transformer Tests	With power off, remove converter. Measure resistance between: (a) Pins 2 and 4 of converter socket (b) Chassis and pin 2 of V1 (c) Chassis and pin 2 of converter socket	 (a) 550 ohms, nominal (b) 7300 ohms (c) Infinite	 (a) Input transformer primary open. (b) Input transformer secondary open (c) Short circuit between transformer windings
10 Grid Resistor Test	With power off, measure resistance between chassis and: (a) Pin 2 of V2 (b) Pin 7 of V2 (c) Pin 2 or 7 of V3	 (a) 1 megohm (b) 4.4 megohm (c) .22 megohm	 (a) R18 open (b) R21, R20 open (c) R23 open
11 (a) Coupling Capacitor Tests	Measure d-c voltage between chassis and: (a) Pin 7 of V1 (b) Pin 2 of V2 (c) Pin 7 of V2 (d) Pin 2 of V3 (e) Pin 4 of V4	Zero d-c voltage	(a) C9 shorted (b) C10 shorted (c) C11 shorted (d) C12 shorted (e) C10 shorted
11 (b) Coupling Capacitor Tests	Connect analyzer (a-c range) between chassis and pin 2 of V3. Clip one end of an insulated test lead to pin 4 of V1. Touch other end of test lead to: (a) Pin 7 of V2 (b) Pin 2 of V2 (c) Pin 4 of V4 (d) Pin 7 of V1 (e) Pin 1 of V1 (turn gain control to clockwise limit)	A change in analyzer reading upon touching each pin	(a) C12 open (b) C11 open (c) C17 open (d) C10 open (e) C9 open
12 Filter Capacitor Test	Remove amplifier input plug. Measure resistance between pins 4 and 6 of input receptacle (highest ohms range)	Reading is infinite after initial kick	Shorted filter, capacitor C1, C2, or C3

Table K4 (concluded).



● gain setting maximum
■ measured with V3 removed
▬ measured with respect to pin 3 or 8 of V3



NOTES

1. In socket chart, lower section of each block gives voltage; upper section of each block gives resistance. Voltages and resistances are measured to chassis except as indicated.
2. Voltages are d-c except as indicated. These are average values to be obtained with 120 v a-c line voltage applied to amplifier, and gain control set to counterclockwise limit.
3. Measurements are made with balancing motor control winding disconnected from amplifier
4. Abbreviations as follows: M = megohm, K = thousand ohms.

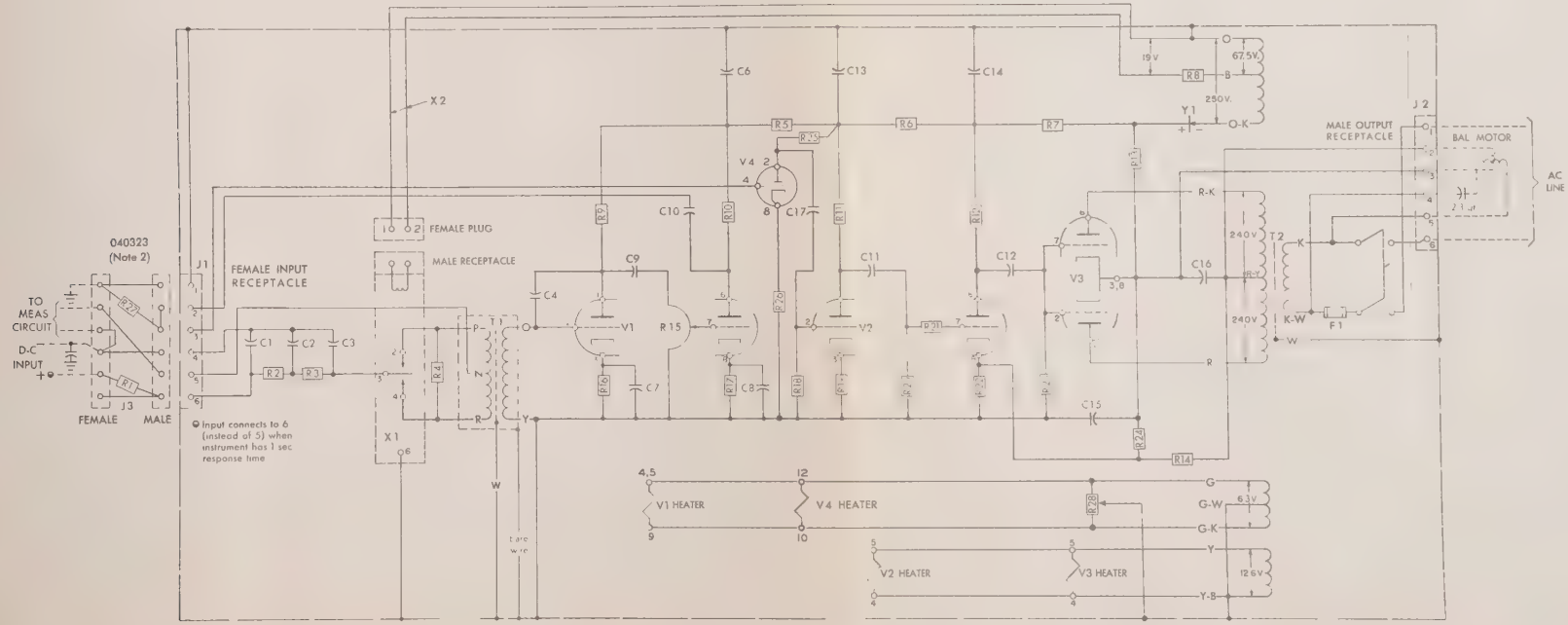


Fig. K6—Schematic of 101120 or 101121 Amplifier with test data.

			L&N Part No.
***R1	18K		11-1-0-59
R2	15K		11-1-0-58
R3	15K		11-1-0-58
R4	67K		11-1-0-66
R5	100K		11-1-0-68
R6	100K		11-1-0-68
R7	10K		11-1-0-56
R8	2700Ω 3W		011623
R9	1 Meg		11-1-0-80
R10	1 Meg		11-1-0-80
R11	1 Meg		11-1-0-80
R12	1 Meg		11-1-0-80
R13	270K		11-1-0-73
R14	22K		11-1-0-60
R15	1 Meg		013138
R16	10K		11-1-0-56
R17	10K		11-1-0-56
R18	1 Meg		11-1-0-80
R19	10K		11-1-0-56
R20	2.2 Meg		11-1-0-84
R21	2.2 Meg		11-1-0-84
R22	1500Ω		11-1-0-46
R23	220K		11-1-0-72
R24	10K		11-1-0-56
R25	1 Meg		11-1-0-80
R26	39K		11-1-0-63
***R27	1 Meg		11-1-0-80
R28	100Ω 2W		013169

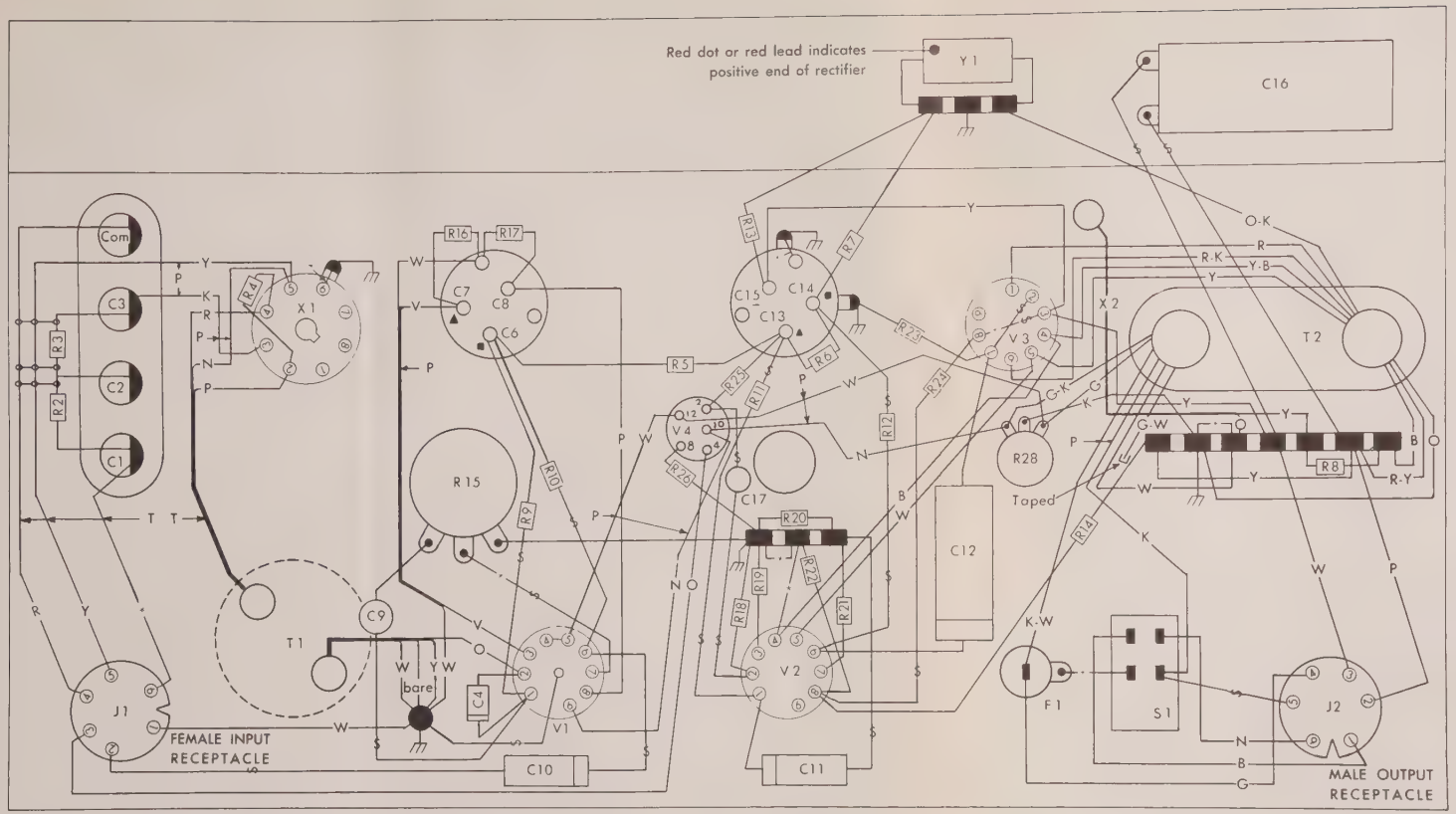
CAPACITORS

C1	1μf	5vDC	023247
C2	1μf	5vDC	
C3	1μf	5vDC	
▲C4	47μμf	500vDC	023238
▲C6	4μf	300vDC	023123
▲C7	25μf	2vDC	
▲C8	25μf	2vDC	
C9	.02μf	450vDC	023096
C10	.022μf	400vDC	23-3-0-20
C11	.022μf	400vDC	23-3-0-20
C12	.1μf	400vDC	23-3-0-8
▲C13	4μf	300vDC	023122
▲C14	4μf	300vDC	
▲C15	25μf	10vDC	
C16	1μf	130vAC	023124
C17	.02μf	450vDC	023096

MISCELLANEOUS

T1	Input Transformer	Std. 21178-39
T2	Power Transformer	019183
▲V1	12AX7	22-1-0-6
▲V2	12AX7	22-1-0-6
▲V3	12BH7	022062
▲V4	7586	022007
▲X1	Converter 60 cycle	354156*
▲X1	Converter 50 cycle	354169**
X2	Converter Cable	037253
▲F1	1 amp Slo-Blo	014049
S1	Line Switch	032197
Y1	Rectifier	057016
	Socket for V1 & V2	40-1-0-8
	Socket for V3	40-1-0-4
	Socket for V4	040285
	Output Receptacle	Std. 3246-176
	Input Receptacle	Std. 3246-174

*For 101120 Amplifier **For 101121 Amplifier
▲Recommended for spare parts stock
***See Note 2, other side



NOTES

1. All resistors are ½ watt, with ±10% tolerance except as noted.
2. Plug (040323) is required when remote amplifier gain control circuit is not required. Resistors R1 and R27 supplied in part 040323.

SYMBOLS

- indicates leads twisted around resistors
- P — indicates tightly twisted leads
- T — indicates three tightly twisted leads
- S — indicates insulated tubing
- indicates tinned wire
- indicates outside foil of paper capacitors

COLOR CODE

K — Black	Y — Yellow
W — White	A — Gray
G — Green	V — Violet
R — Red	P — Pink
B — Blue	S — Slate
N — Brown	T — Tan
O — Orange	

Fig. K7—Wiring diagram of 101120 or 101121 Amplifier.

Section L—NULL BALANCE MEASURING SYSTEMS

PRINCIPLES

The Speedomax W instrument comprises an automatic null-balance measuring system in which balance is accomplished through the use of an electronic amplifer. The essential parts of such a system are, (1) the null-balance measuring circuit, (2) the null detector-amplifier, (3) the balancing motor and linkage, and (4) the display system, i. e., recording and indicating devices.

Fig. L1 illustrates the general plan of the system. In this instance—measurement of emf—the measuring circuit consists of an adjustable calibrated emf connected to oppose the emf being measured. If these two emf's are not equal, an "error" or unbalance current flows as shown and is detected by the input circuit of the amplifier.

After amplification, the error signal is applied to the reversible balancing motor which then works through the mechanical linkage to adjust the calibrated emf. The system is sensitive to the direction of error current so that the motor always adjusts the calibrated emf in the proper direction to reduce the magnitude of the error current. The motor continues to drive until the error current is so small that the amplified signal will no longer produce motor rotation. Amplification is great enough that this occurs when the error current is substantially zero and the calibrated emf differs by only a negligible amount from the emf being measured. A null or balance condition then exists.

While adjusting the calibrated emf, the motor also drives the display system. Pointer position (and also pen position) therefore directly indicates the calibrated emf and hence the emf being measured. The indicator scale may be marked in terms of emf, or in terms of temperature or other variable producing the measured emf.

Although the foregoing illustration applies particularly to emf measurement, the basic method is equally applicable to measurement of resistance. In both instances a precise, known quantity is continuously and automatically adjusted to be equal to the quantity being measured.

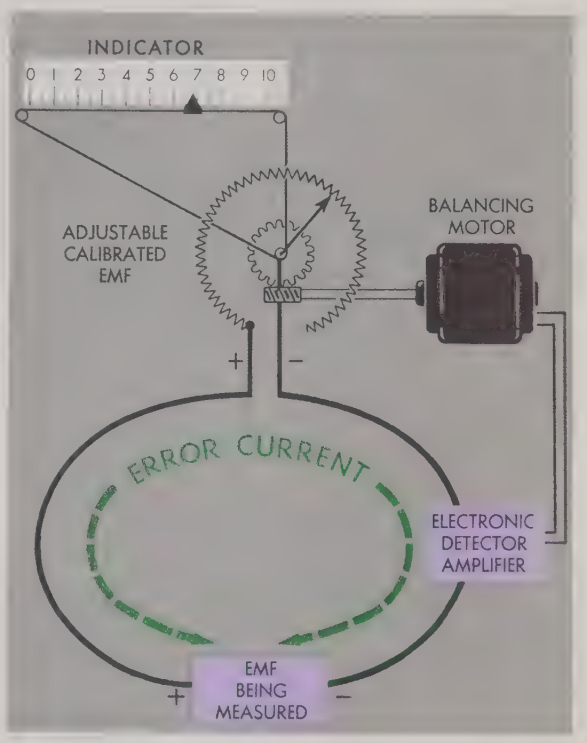


Fig. L1—Schematic illustration of null-balance method applied to emf measurement.

SPEEDOMAX W MEASURING CIRCUITS

The exact layout of the measuring circuit used in a particular Speedomax W instrument will depend of course upon the kind of measurement for which the instrument is to be employed. In almost all cases the circuit will be a variation of either a potentiometer circuit (for emf measurement) or a Wheatstone bridge circuit (for resistance measurement) in which balance is obtained by the positioning of a slidewire contact. Some of the more frequently used variations will be discussed in detail in a later section. At this point however, a consideration of simple potentiometer and bridge circuits will demonstrate how the null-balance method is actually applied in Speedomax W measurements.

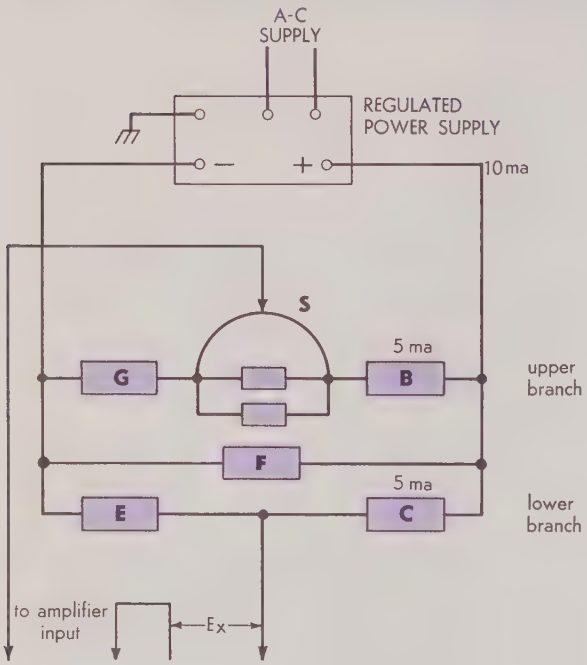


Fig. L2—Potentiometer circuit.

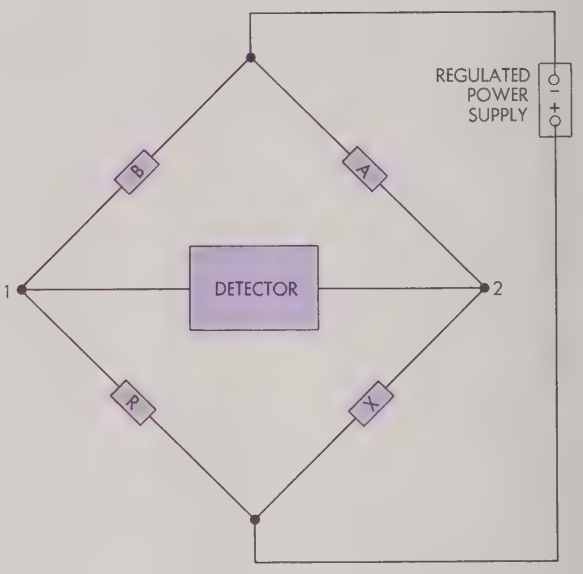


Fig. L3—Simple Wheatstone bridge circuit.

Potentiometer Circuit—An emf potentiometer circuit is shown in Fig. L2. The circuit is arranged with two branches of equal resistance to which current is supplied by the regulated power supply. The magnitude of this current is controlled by a rheostat which is an integral part of the power supply. In Speedomax W potentiometer instruments, it is customary to provide a total drain of 10 ma, which usually divides equally between the two branches.

The regulated power supply is designed for a normal output of 10 ma. The measuring circuit is designed for an input of 10 ma, normally with 5 ma through each branch. However, when the range is below 5-mv full scale, resistor F, Fig. L2, is of such a value that it absorbs part of the 10 ma from the power supply and causes currents less than 5 ma in the measuring branches. This permits the use of larger value circuit resistances, where the required resistor accuracy is more easily obtained. The power supply contains a screwdriver-operated rheostat for adjusting the output current. This rheostat has been adjusted at the factory and should need attention only as indicated in Section P.

During normal measurement, the balancing motor drives the slidewire contact until the emf being measured is balanced by the potential difference existing between the slidewire contact and the junction of resistors E and C. By proper selection of the S, E, and G resistances, this potential difference can be made to vary through the desired measuring range as the contact traverses the slidewire. Resistance values are chosen to provide suppression and range span as described below, and resistor B is then selected to make the total resistance of the upper branch equal to that of the lower branch.

Range Span—Full-scale travel of the Speedomax pointer corresponds to complete traversal of slidewire S by its contact. The voltage drop across the slidewire must therefore be equal to the emf difference between the high and low ends of the desired range. This difference is known as the span and is designated as Es. By Ohm's law,

$$S = \frac{Es}{5}$$

where S is in ohms and Es is in millivolts. Note that S is the shunted resistance of the slidewire. Two shunts are used as shown.

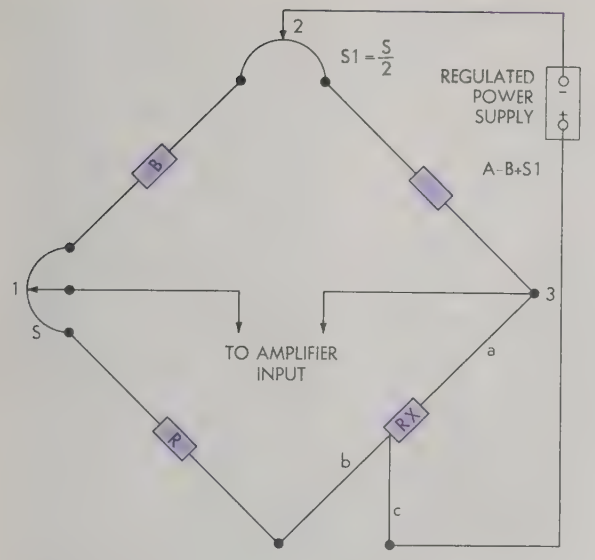


Fig. L4—Simplified diagram of Speedomax W bridge circuit.

Suppression—If the Speedomax scale range starts at zero, resistors G and E are nearly equal. In many instances however, the scale starts at a value greater than zero. This is called zero suppression because the zero is, in effect, shifted below the lower end of the scale. A range of 30-40 mv, for example, is said to have 30 mv zero suppression. In selecting potentiometer circuit resistance values, suppression is provided by making G larger than E. The difference in the voltage drops across these resistors is equal to the suppression. Thus for a range which starts at 30 mv, G must exceed E by 6 ohms (30 ÷ 5 ma).

Some instrument ranges have an upscale zero. Such a range, for example, might be −50 to +50 mv where the zero is at center scale. This is known as zero elevation, or negative suppression. It is obtained by making E larger than G by such an amount that the difference in their voltage drops is equal to the desired zero elevation.

Potentiometer Circuit Characteristics—From the foregoing it will be noted that the potentiometer circuit has the following important characteristics:

(1) The measurement is made by indirect comparison of the unknown emf with a precision standard.

(2) When the potentiometer circuit is balanced, practically no current flows in the source of measured emf, so that there is negligible IR drop in the source. Consequently, the instrument measures the true emf, or open-circuit voltage, of the source.

(3) The resistance between the measuring slidewire and its contact does not affect the measuring accuracy. This is because the contact resistance is in the amplifier input circuit.

Bridge Circuit—Fig. L3 illustrates the simplest form of Wheatstone bridge. In this circuit the potential difference between points 1 and 2 is zero when

$$\frac{X}{A} = \frac{R}{B} \quad \text{or}$$

$$X = \frac{A}{B} R.$$

Therefore, if the R resistance is varied until a null, i.e., bridge balance is obtained, then X, the resistance being measured, can be calculated from the above equation. A and B are called ratio resistors. If A and B are equal, then X = R when the bridge is balanced.

Fig. L4 shows the form of the bridge circuit used in Speedomax W instruments for temperature measurements with Thermohms or other resistance thermometers. As shown, two slidewires, S and S1, are employed. These wires are mounted on a common molding and their contacts move in unison. With the resistance relationships chosen as shown in Fig. L4, it will be seen that, for any contact setting, the resistance between points 1 and 2 is always equal to that between 2 and 3. That is, the ratio arms are always equal, so that at bridge balance, Rx (the resistance being measured), is equal to the resistance of the arm containing R. The measuring range of the bridge circuit is therefore from R to R + S. As with other Speedomax W null-balance circuits, any unbalance causes an error current to flow through the amplifier input circuit. After amplification, this signal is applied to the balancing motor which then drives the slidewire contacts in the proper direction to restore balance.

Bridge Circuit Characteristics—It will be noted that the bridge circuit of Fig. L4 has the following important characteristics:

(1) The measurement is made by comparing the unknown resistance with precision resistances R and S.

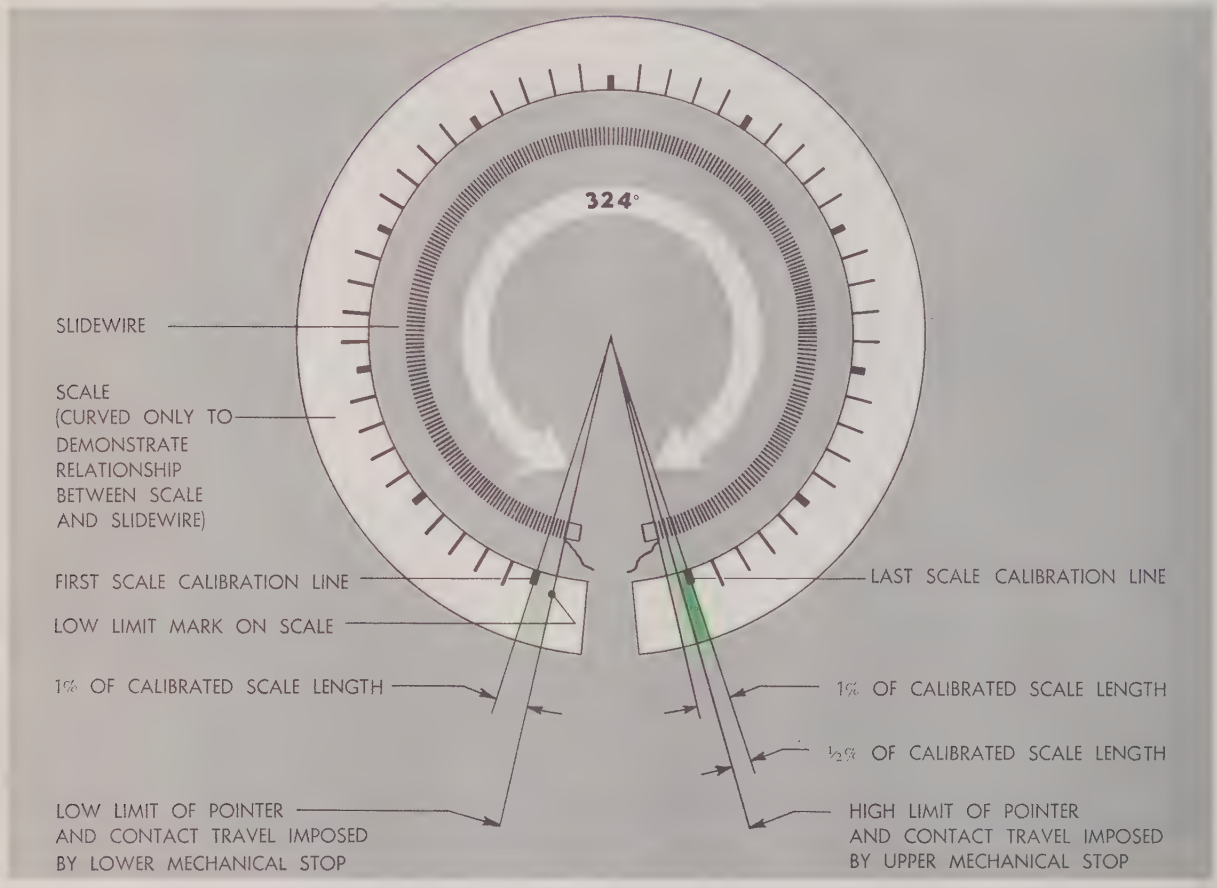

324°
SLIDEWIRE
SCALE (CURVED ONLY TO DEMONSTRATE RELATIONSHIP BETWEEN SCALE AND SLIDEWIRE)
FIRST SCALE CALIBRATION LINE
LOW LIMIT MARK ON SCALE
1% OF CALIBRATED SCALE LENGTH
LOW LIMIT OF POINTER AND CONTACT TRAVEL IMPOSED BY LOWER MECHANICAL STOP
LAST SCALE CALIBRATION LINE
1% OF CALIBRATED SCALE LENGTH
½% OF CALIBRATED SCALE LENGTH
HIGH LIMIT OF POINTER AND CONTACT TRAVEL IMPOSED BY UPPER MECHANICAL STOP

Fig. L5—Schematic illustration of overtravel provision on Speedomax W instruments.

(2) The measuring accuracy does not depend upon the constancy of the regulated power supply voltage. It is only necessary that this voltage be high enough that small bridge unbalance voltages can be detected by the amplifier input circuit.

(3) The resistances between the slidewires and their contacts do not affect the measuring accuracy. This is true because the S and S1 contact resistances are in the amplifier input and the regulated power supply circuits respectively, rather than in the bridge arms.

(4) The measuring accuracy is not affected by the presence of resistance in the leads to the resistance being measured, providing that leads a and b (see Fig. L4) are of equal resistance. This is because a and b are in adjacent arms of the bridge. The c lead, of course, is in the power supply circuit and thus does not affect the accuracy.

OVERTRAVEL

In the interests of simplicity, the preceding discussion has omitted mention of slidewire overtravel. In all Speedomax W instruments, the length and resistance of the measuring slidewire is actually two percent greater than required for the calibrated range span. This allows high and low overtravel as shown schematically in Fig. L5. The reason for overtravel is that it permits checking of instrument calibration at the extreme ends of the range span. If no overtravel were provided, it would be hard to tell whether the instrument was balanced at the scale end or whether it had simply stalled against the mechanical stop without achieving balance.

The extra (overtravel) resistance at the ends of the slidewire does of course complicate the calculation of circuit resistances. In the first place, overtravel allowance must be made when slidewire shunt

values are computed. It is then necessary to compensate for the extra slidewire resistance when calculating the values of other circuit resistors. Details of the calculations are given in Section N.

D-C TO A-C CONVERSION

The zero offset of a null amplifier is defined as that magnitude of the input signal which produces no amplifier ouput. Ideally, zero input produces zero output and there is no offset, but in any actual amplifier this condition will probably not be realized exactly. Since the balancing motor runs until the amplified measuring circuit unbalance will produce no further torque, any offset causes an equivalent balancing error. Thus the practical requirement for a null amplifier is that its offset should be very small (15 microvolts offset is tolerable in Speedomax W amplifiers). If, in addition, this small offset is constant, it can be compensated for simply by a slight shift of the measuring slidewire.

Consequently, it is apparent that the null amplifier must have an exceedingly stable zero. All direct coupled d-c amplifiers are inherently subject to zero instability (caused chiefly by variations in tube characteristics). Such amplifiers are therefore unsuitable for use with d-c null-balance measuring circuits. For this reason, Speedomax W instruments employ a-c amplifiers which have good zero stability. Before being introduced into the amplifying stages, the d-c unbalance of the measuring circuit is changed to a-c of line frequency by means of a vibrator-converter, sometimes called a "chopper."

Operation of the converter, which is on the same chassis as the amplifier, is described in detail in the following section. At this point it is only necessary to state that the converter and the primary winding of an input transformer constitute the amplifier input circuit. The true representation of the input circuit is used in Figs. L6 and L7.

FILTERING

The resistance or voltage being measured may be located at a considerable distance from the Speedomax W instrument. Under this condition, a-c voltages are likely to be picked up in the long connecting leads. In particular, electrostatic and electromagnetic coupling of the leads with power lines and equipment may cause a-c of line frequency—usually 60 cycles—to be introduced into the instrument. Without filtering, this interference signal would be chopped by the converter and would enter the amplifier together with the d-c unbalance signal of the measuring circuit. Although the amplified interference signal may not drive the balancing motor, it does tend to overload the amplifier, thereby decreasing the response to the legitimate signal and causing sluggish instrument performance. If a-c interference were great, complete amplifier paralysis could result.

Input Filter—To minimize the effect of a-c interference developed across the input leads (transverse interference), the Speedomax employs a three-stage R-C filter circuit located on the amplifier chassis. As indicated by Fig. L8, the attenuation at 60 cycles is approximately 7:1 for each stage or a total 60-cycle attenuation of about 343:1 for all three stages.

For the most effective filtering action, the input filter would be connected directly across the amplifier input. See dotted connection, Fig. L6. It would then attenuate the a-c components of all signals entering the amplifier. As will be described however, the Speedomax W filter is arranged to also provide instrument damping; hence it cannot be connected directly across the input. Figs. L6 and L7 show how the filter is connected into potentiometer and bridge type measuring circuits respectively. Note that in the potentiometer circuit, Fig. L6, the filter will attenuate a-c pickup in the primary element and its leads, but does not have the same effect on a-c signals induced in other measuring circuit elements. Similarly, inspection of Fig. L7 will reveal that the bridge circuit filter will attenuate a-c which is picked up in the lower arms of the bridge (including the X resistance and its leads), but will be only partially effective in eliminating a-c signals induced in other circuit elements. Therefore precautions are taken to prevent a-c from being induced in the measuring circuit wiring and components inside the case. As will be described, this is accomplished chiefly by the physical arrangement of the instrument circuit.

Input Circuit Capacitor—A 4-μf capacitor is commonly incorporated in Speedomax W measuring circuits. Connected as shown in Figs. L6 and L7, this capacitor provides a low impedance path for interference developed between the input leads and ground (longitudinal interference). It thus minimizes the amount of such interference entering the amplifier. This capacitor is located at the rear of the instrument case beside the range card.

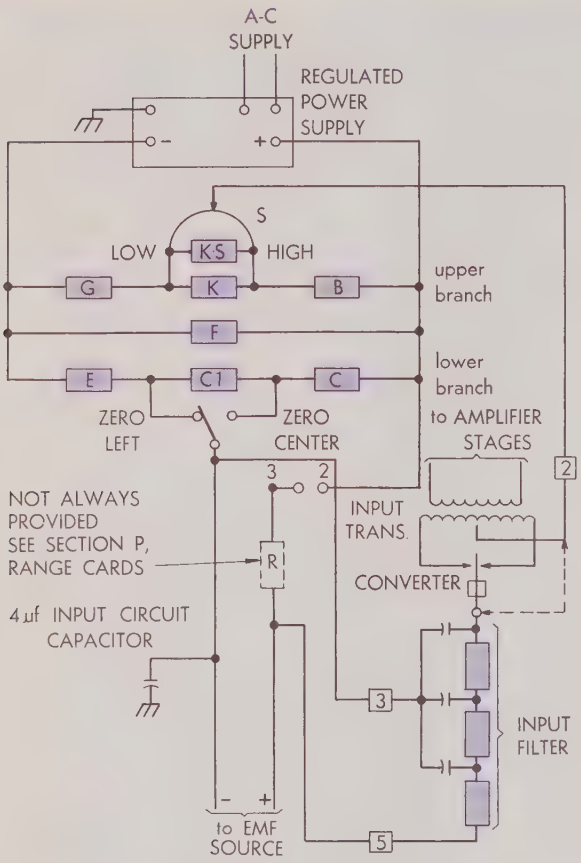


Fig. L6—Speedomax W potentiometer circuit.

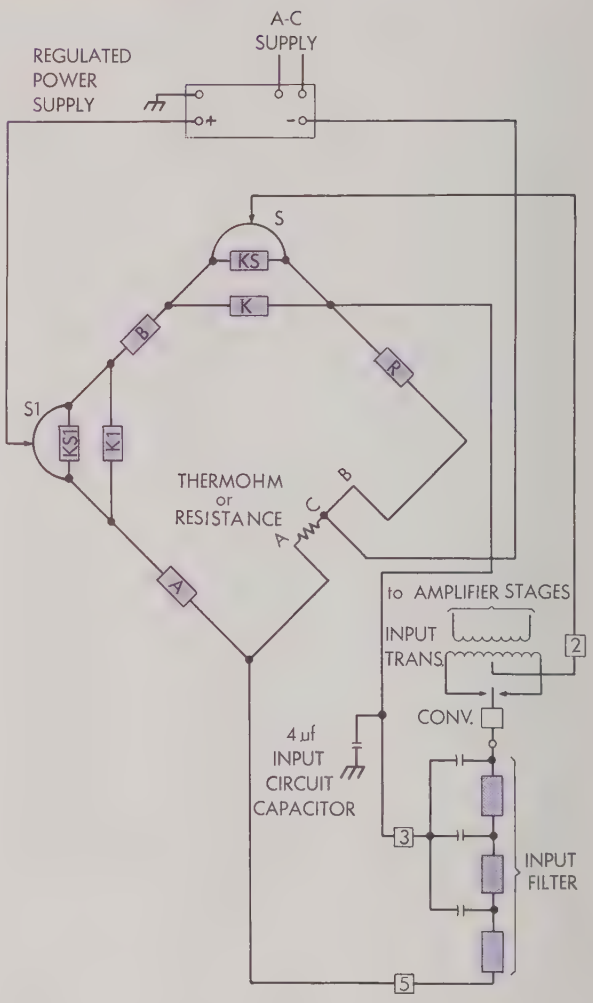


Fig. L7—Speedomax W bridge circuit.

DAMPING

As indicated in Section M, maximum balancing motor torque is developed for an amplifier input equivalent to a measuring circuit unbalance of only 40 microvolts, or 2.0% of a 2 millivolt range span. This steep torque gradient is desirable since it provides high measuring sensitivity, i. e., small deadband. However, in the absence of any other provision, the instrument would constantly overshoot the balance point because any large unbalance would bring the motor up to full speed with no torque reduction until the system approached within 2.0% of balance. To prevent such overshoot and consequent hunting or oscillation of the system, instrument damping is provided.

Damping is effected by the same resistance and capacitance elements that comprise the input filter circuit previously described. In Figs. L9 and L10, the filter has been reduced to a single R-C stage to simplify explanation of the damping method.

Referring to Fig. L9, it can be seen that at balance Ex, Ev, and the voltage across capacitor C, are all equal. Now assume that Ex increases, its polarity remaining as shown. Due to the unbalance between Ex and Ev, an error current flows in the amplifier input circuit as shown, causing the slidewire contact to move upscale to restore balance. As the contact moves, Ev increases causing a charging or damping current to flow through capacitor C and the amplifier input. The damping current is proportional to the rate of change of Ev, and hence to the slidewire contact velocity.

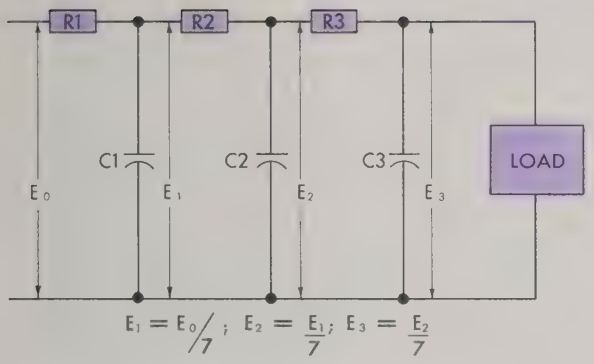


Fig. L8—Approximate 60-cycle attenuation through the input filter.

Now there are two currents flowing in the amplifier input circuit: one proportional to unbalance and causing upscale motion; the other proportional to contact velocity and tending to cause downscale motion. As the balance point is approached, the error current reduces to zero but the damping current persists as long as the system continues to move. Near balance the damping current predominates, applying reverse torque to the balancing motor and thereby braking the system without overshoot.

It can be shown that the damping current is proportional to the capacitance of C, as well as to slidewire contact velocity. Thus the larger C is, the greater will be the damping effect. Also, since the error current flows through resistor R but the damping current does not, an increase in R resistance causes a relative increase in damping current, and hence greater damping effect.

Damping for the bridge circuit is similar to that described above, and is illustrated in Fig. L10. Here it is assumed that the measured resistance, Rx, increases abruptly. Error current flows as shown, causing the slidewire contact to move upscale (upward, in the diagram). The capacitor charging current flows as shown to produce damping action.

CIRCUIT CONFIGURATION

As mentioned above, the input filter may not attenuate a-c voltages appearing in measuring circuit components within the instrument case. Therefore the Speedomax W wiring has been arranged to minimize electrostatic and electromagnetic coupling between high-level circuits (high-voltage wiring to motors, control switches, transformers, etc.) and low-level circuits (measuring and amplifier input circuits).

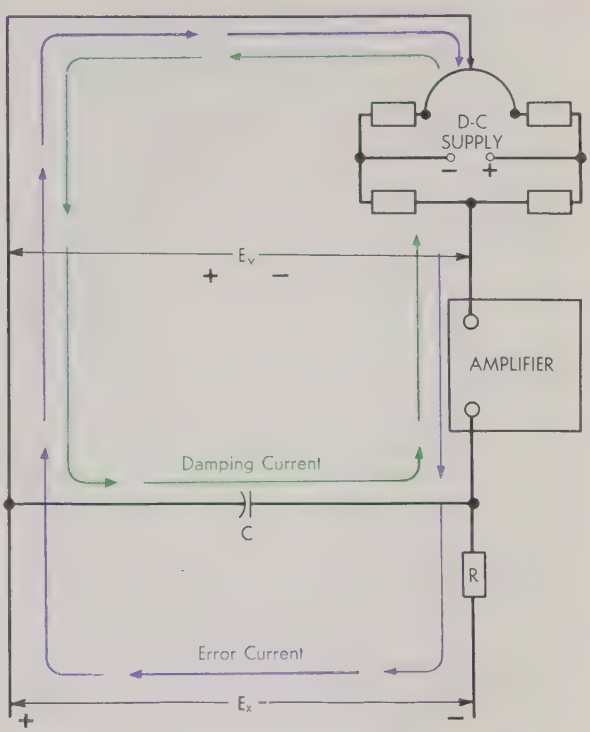


Fig. L9—Damping and error currents in potentiometer circuit.

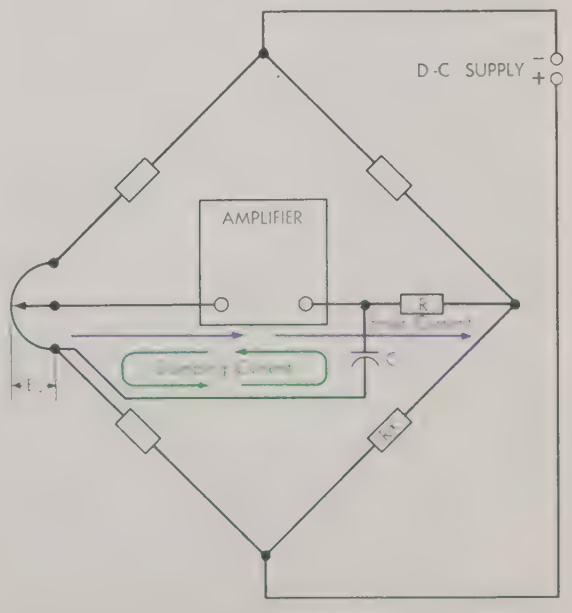


Fig. L10—Damping and error currents in bridge circuit.

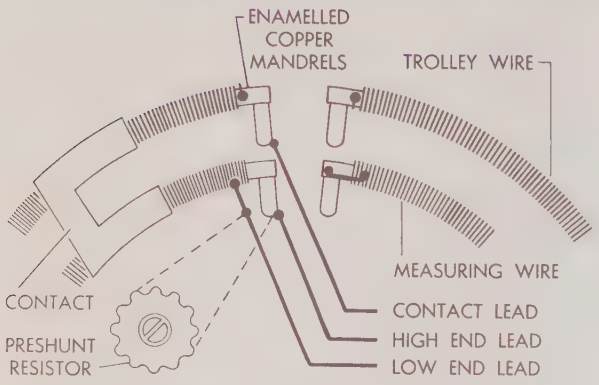


Fig. L11—Configuration of the Speedomax W measuring slidewire.

Reduction of electrostatic coupling is effected by the physical separation of the high-and low-level circuits in the instrument. Thus the wiring is arranged in two separate cables, all high-voltage wiring being routed around the upper rear and side of the case and along the top of the hinged casting, while the measuring circuit wiring is carried around the bottom of the case and casting.

To reduce electromagnetic coupling, the low-level wiring is arranged with minimum effective loop area. Where necessary, this has been accomplished by the twisting together of wires. The measuring slidewire in particular is designed with negligible loop area. As illustrated in Fig. L11, the end of the connection to the high end of the measuring wire is actually made at the low end through the insulated mandrel. A separate trolley wire in close proximity to the measuring wire makes possible a small bridging contact and thereby avoids inductive loops in the contact circuit.

SPEEDOMAX W CHARACTERISTICS

Dead Band—The dead band of a null-balance instrument is defined as the range through which the measured quantity can be varied without causing response, i. e., balancing action. Dead band is conveniently expressed in percentage of scale span. For all Speedomax W instruments with millivolt spans of 1 mv or greater, the dead band rating is 0.15% or less of scale span.

Accuracy—Instrument accuracy is defined as the maximum difference which will exist between the instrument reading and the true value of the measured quantity under rated operating conditions. Accuracy is commonly expressed in percentage of scale span.

Rated accuracy of standard Speedomax W instruments is 0.3% of scale span. This figure includes errors due to dead band, to tolerances in calibrated circuit components (precision resistors, slidewire, regulated power supply), and to tolerances in mechanical components of the balancing and indicating systems. It does not, however, include inaccuracies in the thermocouple, resistance thermometer, or other primary element.

Effect of Source Resistance—Very high resistance in the source of the measured emf has two effects on the performance of a potentiometer instrument. First, it tends to increase dead band because the IR drop across the source resistance reduces the voltage at the amplifier input terminals. Second, it makes for slower instrument response since source resistance is effectively part of the damping resistance (see Fig. L9) and, when very large, will cause overdamping.

The maximum source resistance which may be used with Speedomax W instruments without noticeable effect on either rated accuracy or dead band is dependent upon both the type of amplifier and the millivolt span used. The nominal maximum source resistance values are as follows:

With standard amplifier—2500 ohms at 5 mv.
With high-gain amplifier—2500 ohms at 1 mv.
With high-gain, moderate impedance amplifier—15000 ohms at 1 mv.

Rated accuracy and dead band will be maintained at source resistance values above the nominal maximum values stated above, provided the spans used are not less than those calculated by the following formulas:

Speedomax W with standard amplifier—

$$\text{Span (mv)} = 2 \text{ mv} + \left(\frac{R - 2.5K}{8K}\right) 2 \text{ mv};$$

Speedomax W with high -gain amplifier—

$$\text{Span (mv)} = 0.5 \text{ mv} + \left(\frac{R - 2.5K}{8K}\right) 0.5 \text{ mv};$$

Speedomax W with high-gain, mod. imp. amplifier—

$$\text{Span (mv)} = 1 \text{ mv} + \left(\frac{R - 15K}{56K}\right) 1 \text{ mv};$$

where R is the source resistance and K is kilohms.

To illustrate, suppose it is desired to use a 25K ohm source resistance with a Speedomax W equipped with a high-gain amplifier. What is the minimum span (mv) required?

Using the high-gain formula—

$$\text{Span (mv)} = 0.5 \text{ mv} + \left(\frac{R - 2.5K}{8K}\right) 0.5 \text{ mv}$$

$$= 0.5 \text{ mv} + \left(\frac{25K - 2.5K}{8K}\right) 0.5 \text{ mv}$$

$$= 0.5 \text{ mv} + 1.4 \text{ mv or approximately } 2 \text{ mv.}$$

Note that because the source resistance is increased beyond the nominal maximum value stated for that type of amplifier, the span step response time for the instrument will be increased above its rated value.

Step Response Time—This is the time required for the instrument to come to rest at the new balance point after an instantaneous change in the measured quantity. The rated step response time of standard Speedomax W instruments may be either 1 second or 5 seconds, as ordered.

The span step response time for all spans greater than the minimum values determined from the preceding formulas may be obtained from the following ones:

Speedomax W with standard amplifier or high-gain amplifier—

1-second gearing: $\left(1 + \frac{R - 2.5K}{6K}\right)$ seconds

5-second gearing: $\left(5 + \frac{R - 5.6K}{6K}\right)$ seconds;

Speedomax W with high-gain, moderate impedence amplifier—

1-second gearing: $\left(1 + \frac{R - 22K}{45K}\right)$ seconds

5-second gearing: $\left(5 + \frac{R - 100K}{45K}\right)$ seconds;

where R is the source resistance and K is kilohms.

PART III—TECHNICAL INFORMATION . . . . .

Section M—THE BALANCING SYSTEM . . . . .

The Speedomax W balancing system comprises the detector-amplifier, the balancing motor, and the mechanical system linking the motor to the measuring slidewire contact. Concerning the latter, it is sufficient to say that the balancing motor operates the instrument slidewire shaft through a worm drive having a 100:1 speed reduction for 5-second step response or 16⅔: 1 for 1-second step response. The remainder of this section describes the operation of the amplifier and balancing motor.

For convenience, it will be assumed in the following discussion that the Speedomax W instrument operates from a 120-v, 60-cycle supply. The principles described, however, also apply to 50-cycle instruments.

The balancing motor is a specially-designed two-phase induction motor having two completely separate windings. For correct operation of such a motor, the voltages applied to the two windings must be of the same frequency, the phase of one winding leading or lagging the other by 90 electrical degrees, according to the required direction of motor rotation. Thus the motor can be reversed by a 180-degree phase shift, i. e., phase reversal, in one winding.

The two windings of the balancing motor are called *line winding* and *control winding* respectively. The line winding is connected to the 120-v a-c line through a 2.3-μf capacitor and is thereby supplied with 60-cycle voltage of constant phase and magnitude. The control winding is energized from the power output stage of the detector-amplifier. Thus for proper operation of the null balance system, the amplifier must furnish a 60-cycle voltage, leading or lagging the line winding voltage by 90 degrees, according to the direction of measuring circuit unbalance. The magnitude of the amplifier output should be approximately proportional to the unbalance, and must be large enough to produce motor rotation for an unbalance of about 10 microvolts using a standard amplifier or about 5 microvolts using the high-gain types.

In fulfilling the preceding requirements, the following distinct functions are involved: (1) conversion of the d-c unbalance signal to 60 cycles; (2) amplification of the a-c signal to the level required for motor operation; (3) operation of the motor in the proper direction to restore balance. Each of these functions will be described.

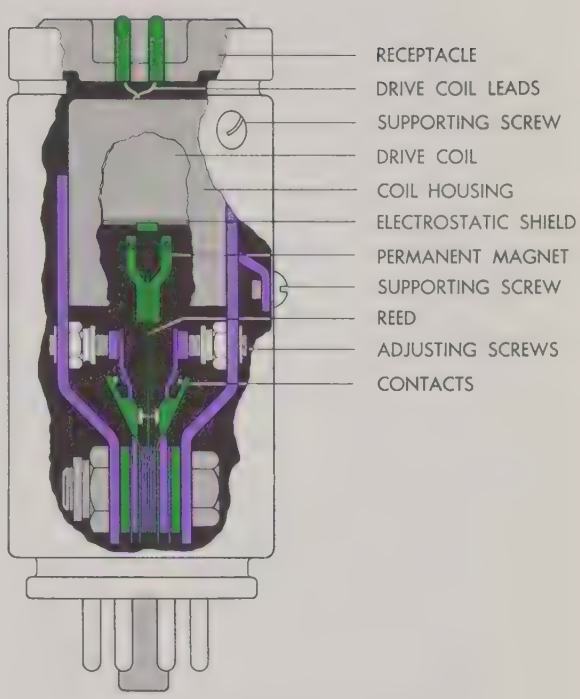


Fig. M1—Speedomax W converter.

CONVERSION

D-c to a-c conversion is accomplished by the synchronous converter mounted on the amplifier chassis. Fig. M1 shows the internal structure of this unit and Fig. M2 illustrates how it is connected with the input transformer to form the amplifier input circuit.

The converter is essentially a single-pole double-throw switch which is operated by the motion of the metal reed. The drive coil at the top of the unit is supplied with 60-cycle current from the amplifier power transformer, and thus produces a 60-cycle alternating magnetic field. Because of the small permanent magnet at its upper end, the reed vibrates in response to the magnetic field, thereby operating the converter contacts in synchronism with the 60-cycle line.

Referring to Fig. M2, it can be seen that any unbalance voltage from the measuring circuit is connected alternately to the two halves of the input transformer primary winding by the action of the converter. Thus, direct current flows first through one-half of the winding and then through the other

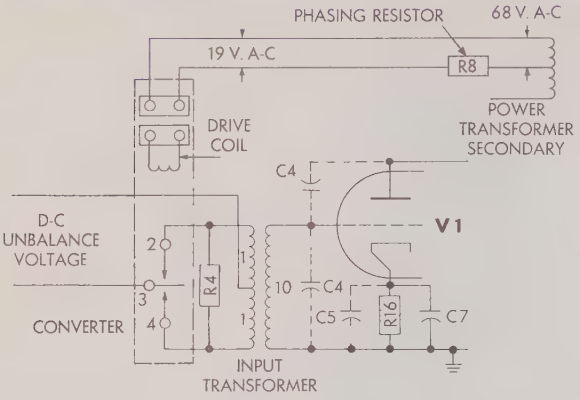


Fig. M2—Typical converter circuit. Refer to Figs. K2, K4 and K6 for actual location of C4, and C5 where used.

half in the opposite direction. In consequence, a 60-cycle alternating voltage — approximately a square wave—is induced in the transformer secondary and applied to the grid of the first amplifier tube V1.

The magnitude of the induced secondary voltage is proportional to the primary voltage, and hence to the magnitude of the d-c measuring circuit unbalance voltage. Moreover, the phase of this voltage depends upon the direction of the d-c unbalance voltage. For, if the polarity of the unbalance signal is reversed, then the transformer primary current flows in the opposite direction during each half cycle, thereby reversing the instantaneous polarity of the secondary voltage, i.e., shifting its phase by 180 degrees.

Converter—The synchronous converter, whose operation has just been described, is a self-contained plug-in unit, sealed to prevent the entrance of dust. Since the contacts are part of the low-level circuitry, it is important that they be shielded from the 60-cycle drive coil. As shown in Fig. M1, an electrostatic shield is provided. In addition, the long skirt of the coil housing minimizes magnetic flux from the drive coil in the region of the contacts.

The converter is adjusted so that during normal operation each set of contacts is closed 45% of the time. That is, the converter action is break-before-make. As shown in the simplified diagram, Fig. M2, a 10,000 ohm resistor is connected across the outer contacts (terminals 2 and 4 of the converter socket). The resistor decreases the effective impedance of the input circuit to the value required for good system damping. This arrangement is equivalent to an increase in converter closure time (i.e., make-before-break action) but has an advantage in that closure times are not as critical.

Input Transformer—As indicated in Fig. M2, this is a 1:10 step-up transformer. Since the transformer is in the low-level circuit, special precautions have been taken in its design: (1) the transformer coils are of "humbucking" construction, i.e., each coil section is wound in such a way that voltages induced by external magnetic fields are canceled out; (2) the coil is enclosed within four concentric mumetal shells, for magnetic shielding; (3) the outer case of the transformer provides electrostatic shielding.

VOLTAGE AMPLIFICATION

As has been described, the conversion stage produces an a-c voltage whose magnitude and phase depend upon the magnitude and polarity, respectively, of the d-c unbalance signal. This a-c voltage must now be sufficiently amplified to drive the power stage which, in turn, will operate the balancing motor. Voltage amplification in the standard amplifiers is provided by two 12AX7 twin-triode tubes, and in the high-gain types by an additional stage—a total of four or five consecutive voltage stages employing conventional resistance-capacitance coupling. Plate voltage is supplied to these stages from the power transformer through a selenium rectifier and resistance-capacitance filter.

Because of the small magnitude of the a-c signal in the first amplifier stage(s), special care is taken to prevent the entrance of interference at these stage(s). Thus the heater sections of the first stage(s) are operated in parallel from a separate 6.3-volt winding of the power transformer, instead of using the same 12.6-volt supply as the other tubes. This lower voltage minimizes pickup from the heaters. Capacitors C4 and C5, Fig. M2, represent additional interference precautions. While these low-valued capacitors have negligible effect on the 60-cycle signal, they effectively bypass any high frequency transient voltages entering the amplifier.

A gain control on the standard and high-gain amplifiers is provided between the first two voltage amplifier stages and is used to reduce the gain to the correct value. On the high-gain types, provision is also included for remote gain operation. See Figs. K4 and K6. On all except the lowest range spans, full amplifier gain would make the system oversensitive with consequent overshoot and hunting.

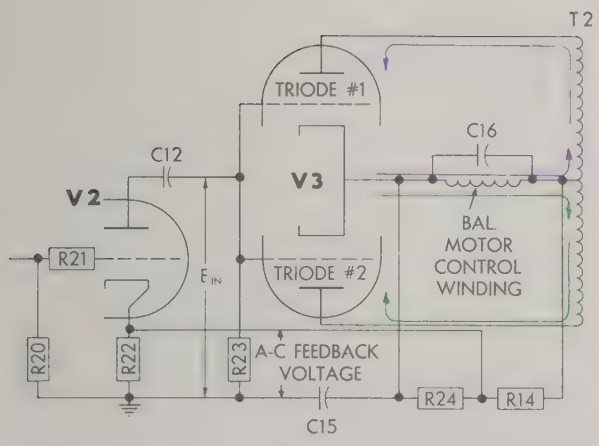


Fig. M3—Amplifier output stage. Figure also shows feedback circuit used for amplifier stabilization.

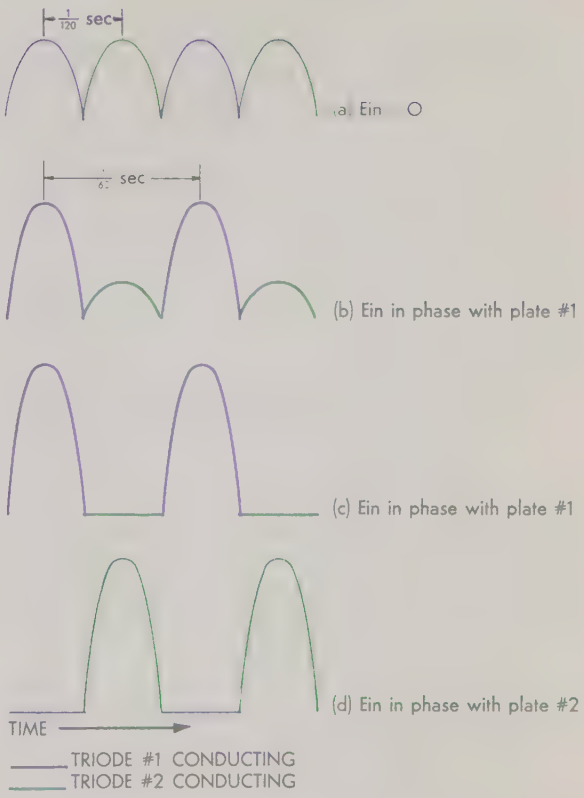

$\frac{1}{120}$ sec
(a) Ein = 0
$\frac{1}{60}$ sec
(b) Ein in phase with plate #1
(c) Ein in phase with plate #1
(d) Ein in phase with plate #2
TIME
TRIODE #1 CONDUCTING
TRIODE #2 CONDUCTING

Fig. M4—Amplifier output current wave forms.

BALANCING MOTOR OPERATION

Fig. M3 is a simplified representation of the amplifier power output stage which produces balancing motor operation. As shown, the stage employs both halves of a 12BH7 twin-triode tube. Plate voltage for the two triodes is supplied from opposite ends of a center-tapped, high-voltage winding of the amplifier power transformer. Either one side or the other of the balancing motor control winding, depending upon amplifier type, connects to the transformer center tap, the other side being common to the cathode circuits of both triodes. See Figs. K2, K4, and K6. A 1-μf capacitor tunes the control winding to 60-cycle resonance, i.e., at 60 cycles, the impedance of the motor-capacitor parallel combination is almost purely resistive.

The 60-cycle signal from the voltage amplifier stages (Ein, Fig. M3) is applied simultaneously to both grids of the output stage (note that capacitor C15 provides an a-c ground for the two cathodes, so the input signal is impressed between cathode and grid, as it should be).

First, consider the case when the system is balanced so that Ein has zero magnitude. On one-half cycle of line voltage, the plate of triode #1 (Fig. M3) goes positive and a current flows as indicated by the purple arrow. At the same time, the other plate goes negative and therefore no current can flow through triode #2 on this half cycle. During the next half cycle, the plate voltages are reversed, so that no current flows in triode #1 but triode #2 conducts as indicated by the green arrow. In short, this is ordinary full-wave rectification, the two halves of the tube conducting on alternate half cycles of line voltage. Thus the amplifier output current is as shown in curve (a), Fig. M4. Since the fundamental frequency component of this pulsating direct current is 120 cycles per second, it does not run the motor.

Now suppose the measuring circuit is unbalanced in such a direction that Ein is in phase with the #1 plate. Then on the half cycle when this plate is positive, its control grid is also positive and triode #1 conducts more than formerly. The #2 grid, however, is 180 degrees out of phase with #2 plate, so that on the succeeding half cycle, the #2 triode conducts less than before. In consequence, the amplifier output current appears as in curve (b), Fig. M4. Since this waveform repeats itself every sixtieth of a second, it is a 60-cycle current. Such a current can be considered as consisting of a 60-cycle sine wave plus higher harmonics, all superimposed on a d-c component. So

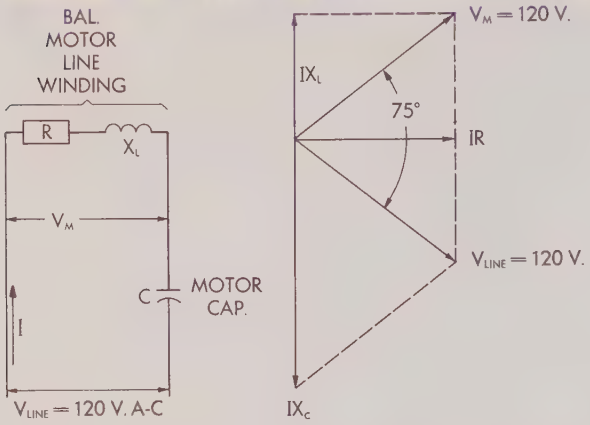


Fig. M5—Equivalent circuit and phasing diagram for balancing motor line winding. The phase relationships shown are those existing with the motor not running, i.e., system balanced.

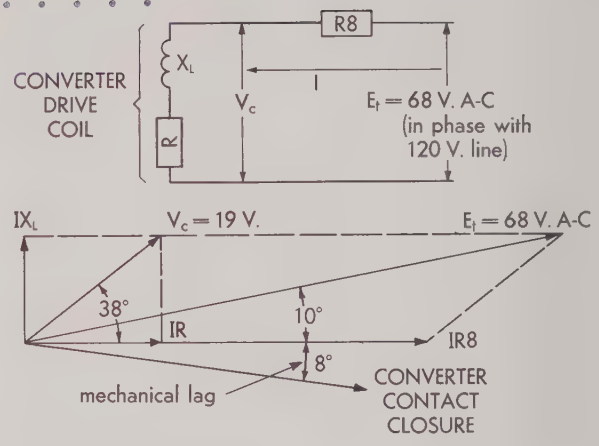


Fig. M6—Equivalent circuit and phasing diagram for the converter drive coil.

far as motor operation is concerned, the d-c and higher frequency components have no effect. The 60-cycle sine wave component, however, will produce motor rotation as previously described; (it will be shown that this component has the proper relationship to the line winding voltage).

Curve (b), Fig. M4, shows the amplifier output current for a small value of input voltage Ein. For a larger unbalance, the resulting increase in Ein would cause triode #2 to cut off and would also increase current flow through the #1 triode plate during its positive half cycle. Thus the output current would be somewhat as shown by curve (c), Fig. M4. It is evident that this current has a larger 60-cycle component than curve (b). That is, the effective component of the amplifier output is approximately proportional to the system unbalance (which is one of the requirements previously stated).

If the direction of system unbalance is reversed, the input voltage Ein is shifted by 180 degrees. Thus the grid and plate voltages will be of the same phase in triode #2 but of opposite phase in triode #1, and the amplifier output current will be as shown by curve (d), Fig. M4. It is obvious that this current is 180 degrees out of phase with that of curves (b) and (c) and will therefore run the balancing motor in the reverse direction. Thus the direction of motor rotation depends upon the direction of unbalance, as required for proper balancing action.

Note that because of the additional stage in the high-gain type amplifier, connections to the balancing motor are reversed in the amplifier output. Instrument wiring thus remains the same regardless of the type of amplifier being used.

As previously stated, capacitor C16 tunes the motor control winding to 60-cycle resonance. Thus the 60-cycle current and voltage are in phase, so that foregoing statements concerning the 60-cycle amplifier output current component also apply to the 60-cycle voltage component across the control winding.

PHASING

From the foregoing discussion it can be seen that phase relationships are of great importance in the operation of the balancing system. The final requirement, of course, is that the 60-cycle voltage which the amplifier delivers to the balancing motor control winding shall differ in phase from the line winding voltage by 90 degrees. In the Speedomax W instrument, this condition is obtained by proper phase adjustments at both the motor line winding and the converter drive coil.

Fig. M5 shows the phase relationships for the motor line winding. As indicated, the use of the 2.3-μf phasing capacitor in series with the winding produces an applied voltage of 120 v, leading the line by 75 electrical degrees.

Phase relationships for the converter are shown in Fig. M6. Here it can be seen that phasing resistor R8 reduces the voltage across the converter to the required value of 19 v and also holds the current lag to 10 degrees. There is an additional mechanical lag of 8 degrees between converter coil current and actual contact closure, so that the converter output signal lags the line by 8 + 10 = 18 degrees.

Thus with line winding voltage leading the line by 75 degrees and converter output lagging by 18 degrees, the total phase difference between these two signals is 18 + 75 = 93 degrees. Although the converter output signal undergoes negligible phase shift in the voltage amplifier stages, there is some phase advance in the power output stage since output phase is affected by both plate and grid voltages of the 12BH7 tube. This reduces the phase difference to very nearly 90 degrees. In brief, the overall effect is to deliver maximum quadrature voltage at the motor control winding.

STABILIZATION

Fig. M3 shows the arrangement used to stabilize the Speedomax W amplifier against variations in line voltage. As shown, resistors R24 and R14 are connected across the balancing motor control winding. Furthermore, R24 is shunted, for a-c only, by R22, the cathode resistor of the last voltage amplifier stage. Thus part of the a-c component of the control winding voltage is fed back to the input of the final voltage stage.

Examination of Fig. M3 will show that the a-c feedback signal mentioned above is of opposite phase to the normal input signal on the grid of the final voltage amplifier, i.e., it is inverse feedback. This feedback signal therefore always tends to reduce the magnitude of the motor control voltage. Thus when the motor voltage tends to drop because of a decrease in line voltage, the magnitude of the a-c feedback voltage also drops, so that motor voltage does not decrease as much as it otherwise would. In short, the feedback always acts to lessen changes in performance due to line voltage variations. In similar fashion it reduces changes due to aging of tubes. A further advantage is that the feedback tends to suppress the 120-cycle and d-c components on the motor control winding and thereby reduces heating in the motor.

TORQUE CHARACTERISTIC

For small values of measuring circuit unbalance, the torque developed by the motor is approximately proportional to the unbalance. This relationship is limited by saturation of the amplifier. Thus as unbalance increases, motor torque also increases, becoming 0.75 oz.-in., i.e., sufficient to drive the mechanical system, for an unbalance of about 10 microvolts. At an unbalance of about 40 microvolts, the motor torque is maximum since the amplifier saturates for larger inputs.

Section N—MEASURING CIRCUITS

While the general principles discussed in Section M apply to all Speedomax measuring circuits, the actual circuits used vary according to the kind of measurement for which the instruments are intended. This section discusses some frequently used circuits and shows the calculations involved in the determination of circuit constants.

GENERAL INFORMATION

Accuracy of Components—The regulated power supply used in potentiometer circuits is adjusted to within ±0.1% of the nominal value of 1.05v used for calculations. Similarly, all calibrated resistances, such as measuring slidewires, fixed resistors, compensators, etc., are adjusted during manufacture to within 0.05% of the nominal or calculated value.

Measuring Slidewire—Since it is inconvenient to wind slidewires to precise value, they are shunted to the required resistance. Thus Speedomax W measuring slidewires for standard range emf and thermocouple potentiometer circuits are manufactured to a nominal 400-ohm value and shunted to 200 ohms. This initial shunting is done with the preshunt resistor located on the slidewire molding. The standard 200-ohm value makes the measuring slidewire an interchangeable part and also permits range changes without requiring slidewire replacement. Shunting of the slidewire to the final value needed for a specific range is accomplished with a second shunt resistor which is on the instrument range card.

EMF POTENTIOMETER CIRCUIT

The general principles of the Speedomax W emf potentiometer circuit have been described in Section L. As stated there, it is a two-branch circuit (see Fig. N1), the current in each branch being 5 milliamperes to provide a total drain of 10 milliamperes.

Resistance Values—Fig. N1 shows the standard letter symbols used to designate calibrated resistances of the emf potentiometer circuit. The method of calculating resistances follows:

Resistor KS—This resistor is mounted on the disk with slidewire S. All other measuring circuit resistors, marked in Fig. N1, are mounted on the range card.

Resistor F—This resistor is used only when the range is below 5-mv full scale and resistor C1 is used only for zero-center ranges.

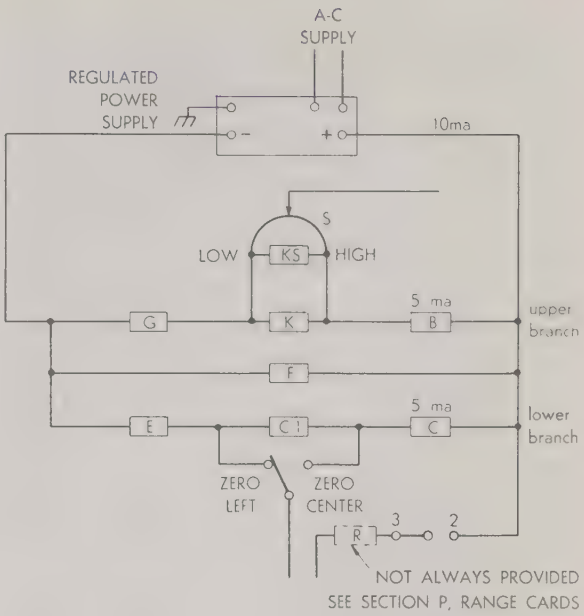


Fig. N1—Diagram for range card calculations for emf potentiometer measuring circuit.

Resistor R—This resistor is connected to the positive input side and is provided on range cards ordered with the input fail-safe feature. For upscale input fail-safe operation, resistor R is connected by a jumper between points 2 and 3.

The values of the various measuring circuit (range card) resistors and of the final shunted value of slidewire S are obtained as outlined below.

The current in each of the two main branches (upper and lower) of the circuit is normally 5 ma. This is changed, as indicated below, when resistor F is used as a third branch.

Slidewire S—The preshunted value of this slidewire is 200 ohms, but it is shunted by resistor K so that its IR drop is equal to the desired millivolt span plus 2% for overtravel (1% at each end). That is:

$$S = \frac{1.02 \times Es}{5} = 0.204\ Es \text{ ohms}$$

where:

S = final shunted value of slidewire S

Es = desired span in millivolts = $E_H - E_L$, where E_H and E_L are the high and low end millivoltages of the range, respectively.

Resistor K—This resistor shunts the preshunted slidewire (200 ohms) down to the calculated value of the slidewire. That is:

$$K = \frac{200 \times S}{200 - S} \text{ ohms}$$

where:

S = final shunted value of slidewire S in ohms.

Resistor E—This resistor is normally 1.0 ohm unless such value would cause the G coil to be less than 0.8 ohm, in which case the E value is increased in 0.5-ohm steps until G is larger than 0.8 ohm.

Resistor G—The G resistor balances out the resistance of the E resistor and in addition, it must provide for zero suppression when this is required. Furthermore, the 1% overtravel resistance at the end of the slidewire is effectively part of the G resistor and must be subtracted as resistor G is calculated. That is:

$$G = E + \frac{Esup.}{5} - \frac{1\% Es}{5}$$

$$= E + 0.2 \text{ Esup.} - 0.002 \text{ Es ohms}$$

where:

Esup. = the zero suppression in millivolts
Es = desired span in millivolts
E = value of E resistor in ohms.

Resistor C1—In order to move the zero point of the slidewire from the left to the center, the detector must be moved by an IR amount equal to one-half the desired span. This is accomplished by using resistor C1 and making the connection on the "zero center" side of the C1 resistor. That is:

$$C1 = 1/2 \times \frac{Es}{5} = 0.1 \text{ Es ohms}$$

where:

Es = desired span in millivolts.

Resistor C—The total millivolt drop across the parallel branches (upper and lower) is 1050 millivolts. With a 5-ma current in each branch, the branch resistance must then be 1050 ÷ 5 or 210 ohms. Thus:

$C = 210 - E - C1$

in which:

C1 = zero when the zero-left function only is used

Resistor B—The branch circuit resistance (see above) is 210 ohms. The B resistor makes up the difference between this value and the sum of values of resistor G and slidewire S. Thus:

B = 210—G—S ohms.

Resistor R—The input fail-safe resistor is calculated as follows:

$$R = \frac{82 \times 10^6}{Es} \text{ ohms.}$$

If the calculated value of R is not a commercial standard resistance value, the nearest commercial standard above this value should be used. This provides for a fail-safe time of about 2½ seconds for a 1-second instrument. For a faster or slower time, decrease or increase the value of the R resistor respectively.

Range below 5-mv full scale—On any range below 5-mv full scale, the branch current values must be changed to keep the resistances to practical values. For the low millivolt spans the following calculations apply:

S = 1.02 Es ohms
E = 1.0 ohm or such larger value in 0.5-ohm steps needed to make G greater than or equal to 0.8 ohm.
G = E + Esup. — 0.01 Es ohms
B = 1050 — G— S ohms
C1 = 0.5 Es ohms
C = 1050 — C1 — E ohms
F = 131.25 ohms

Under these conditions there is 1 ma in each main branch (upper and lower) and 8 ma in the F branch.

THERMOCOUPLE POTENTIOMETER CIRCUIT

The Thermocouple — For electrical measurement of temperature, the thermocouple is the most frequently used primary element. A thermocouple consists of two dissimilar metal wires joined together (usually welded) to form a measuring or "hot" junction at one end. The opposite ends of the thermocouple wires are connected to an instrument which measures the output emf of the couple. Fig. N2 shows this arrangement for a thermocouple composed of iron and constantan (a copper-nickel alloy).

As shown in Fig. N2, copper leadwires are ordinarily used to connect the emf measuring circuit to the thermocouple wires. This results in two addi-

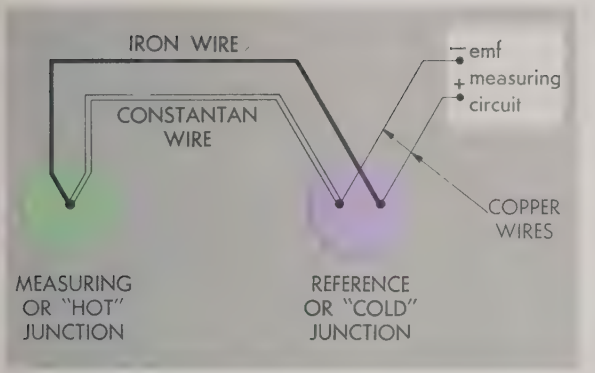


Fig. N2—Basic thermocouple circuit.

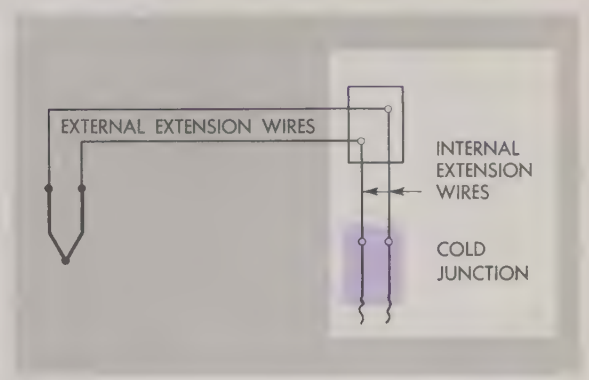


Fig. N3—Extension of thermocouple cold junction to Speedomax W range card.

tional connections of dissimilar metals, i.e., an iron-copper connection and a constantan-copper connection. These two connections are always close to each other so that they are at the same temperature. Together, they form the so-called "cold" or reference junction of the thermocouple.

Extension Wires—In order to provide reference junction compensation, as will be described, the cold or reference junction must be located at the Speedomax range card. This is accomplished by the use of extension wires to connect the thermocouple to the instrument terminal board. In addition, internal extension wires are used to further connect from the terminal board to the range card. Fig. N3 indicates this arrangement. Note that the extension wires serve to actually *extend* the couple to the range card. These wires must therefore have thermoelectric characteristics similar to those of the couple. Usually the extension wires are composed of the same materials as the thermocouple wires themselves. In some cases however, wires of different composition but similar thermoelectric properties are employed.

Conversion Tables—For a given type of thermocouple, the millivoltage outputs corresponding to various hot-junction temperatures are given in a thermocouple conversion table. These tabular values are based upon the use of a couple whose cold junction is at the reference temperature specified in the table. This reference temperature is usually 32 F (0 C).

Measuring Circuit—The thermocouple output is measured by a potentiometer circuit similar to that employed for emf measurements. It is a two-branch circuit (Fig. N4), the current in each branch being 5 ma, to provide a total drain of 10 ma. Calculations for determining circuit resistances will be given. The D resistor however, merits separate consideration since it provides reference junction compensation for the circuit. This is explained in the following discussion.

As has been stated, the thermocouple conversion table gives output emf's corresponding to hot-junction temperatures providing the cold junction is at the specified reference temperature of the table. When cold-junction temperature is higher than the reference value, the actual thermocouple output is less than the tabulated emf. It can be shown that this decrease in output is equal to the emf of a similar couple whose cold junction is at reference temperature and whose hot junction is at the cold-junction temperature of the actual couple. In brief, the output emf of any thermocouple is equal to the tabulated value corresponding to hot-junction temperature minus the tabulated value corresponding to the actual cold-junction temperature.

For convenience in computing measuring circuit millivoltages, the thermocouple cold junction is assumed to be at the reference temperature of the conversion table. Actually, of course, cold-junction temperature in the Speedomax W is considerably higher than this reference value. Moreover, the cold-junction temperature varies somewhat according to operating conditions. Thus the instrument reading would be low and unstable if no compensating device were used.

A special temperature-sensitive resistor, D, provides the necessary cold-junction compensation. With constant 5-ma current flowing through D, any change

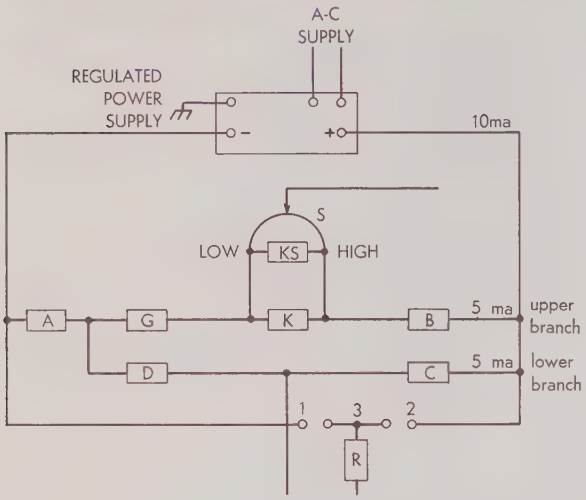


Fig. N4—Diagram for range card calculations for thermocouple potentiometer measuring circuit.

in its temperature produces a corresponding change in potential drop across it and thereby moves the balance position of the slidewire contact up or downscale. The D resistor is composed of copper and nickel in such proportions that, over a limited range, its temperature characteristic matches that of the thermocouple being used. That is, with 5-ma current flow, the change in potential drop across D for a given temperature variation is equal to the change in output of a thermocouple subjected to the same temperature variation. Since the thermocouple cold junction is physically part of the D resistor, both resistor and junction are subject to the same temperature variations. Therefore, the D resistor automatically changes the calibrated emf by an amount equal to the change in thermocouple emf due to reference junction change so that the balance point does not change.

Resistance Values—Fig. N4 shows the standard letter symbols used to designate calibrated resistances of the thermocouple potentiometer circuit. The method of calculating resistances follows:

Resistor KS—This resistor is mounted on the disk with slidewire S. All other measuring circuit resistors, marked in Fig. N4, are mounted on the range card.

Resistors A and R—These resistors are provided on all thermocouple range cards. However, if the input fail-safe feature is not used, resistor R is not connected by a jumper to either point 1 or point 2. On the other hand, for downscale input fail-safe operation resistor R is connected by a jumper to point 1 and for upscale input fail-safe operation resistor R is connected by a jumper to point 2.

The values of the various measuring circuit (range card) resistors and of the final shunted value of slidewire S are obtained as outlined below.

The current in each of the branches (upper and lower) of the circuit is normally 5 milliamperes.

Resistor A—This resistor is the same value (46.000 ohms) for all circuits so as to place slidewire S in the center of the potential drop for input fail-safe action.

Slidewire S—The preshunted value of this slidewire is 200 ohms, but it is shunted by resistor K so that its IR drop is equal to the desired span plus 2% for overtravel (1% at each end). That is:

$$S = \frac{1.02 \times Es}{5} = 0.204\ Es \text{ ohms}$$

where:

S = final shunted value of slidewire S

Es = desired span in millivolts = $E_H - E_L$, where E_H and E_L are the high and low millivoltages of the range, respectively, which are equivalent to the temperatures at these points. The values of E_H and E_L are obtained from conversion tables for a specific thermocouple.

Resistor K—This resistor shunts the preshunted slidewire (200 ohms) down to the calculated value of the slidewire. That is:

$$K = \frac{200 \times S}{200 - S} \text{ ohms}$$

where:

S = final shunted value of slidewire S in ohms.

Resistor D—All D resistors have a resistance of 6.100 ohms at the nominal operating temperature of 105 F (40.5 C). However, the resistance of a given D resistor is dependent upon temperature and the type thermocouple used. The basic resistance values, at 32 F (0 C), of D resistors for the more common thermocouples are listed in Table N1.

ISA TYPE	TYPE COUPLE	D_{32} (ohms)
J	Iron-Constantan	5.6820
K	Chromel-Alumel	5.7740
T	Copper-Constantan	5.7734
S	Plat. 10% Rhodium-Plat.	6.0524
R	Plat. 13% Rhodium-Plat.	6.0526
E	Chromel-Constantan	5.6100

Table N1—Resistance values of automatic reference junction resistors used in Speedomax W thermocouple potentiometer instruments.

Resistor G—The G resistor balances out the base resistance of the D resistor and, in addition, it must provide for zero suppression when this is required. Furthermore, the 1% overtravel at the end of the slidewire is effectively part of the G resistor and must be subtracted as resistor G is calculated. That is:

$$G = D_{32} + \frac{E_L}{5} - \frac{1\% \, Es}{5}$$

$$= D_{32} + 0.2E_L - 0.002 \text{ Es ohms}$$

where:

D_{32} = base resistance values (in ohms) of D resistor for type thermocouple used

E_L = value at low end of span in millivolts

Es = desired span in millivolts.

Resistor C—The total millivolt drop across the parallel branches (upper and lower) is 1050 – 460 or 590 millivolts. With a 5-ma current in each branch, the resistance must be 590 ÷ 5 or 118 ohms. Thus:

$$C = 118 - D_{105}$$

$$= 118 - 6.100 = 111.9 \text{ ohms}$$

where:

D_{105} = value of D resistor at 105 F (6.100 ohms).

Resistor B—The branch circuit resistance is 118 ohms (see above). The B resistor makes up the difference between this value and the sum of the values of resistor G and slidewire S. Thus:

$B = 118 - G - S$ ohms.

Resistor R—The input fail-safe resistor is calculated as follows:

$$R = \frac{39 \times 10^6}{Es} \text{ ohms.}$$

If the calculated value of R is not a commercial standard resistance value, the nearest commercial standard above this value should be used. This provides for a fail-safe time of about 2½ seconds for a 1-second instrument. For a faster or slower time, decrease or increase the value of R respectively.

THERMOHM BRIDGE CIRCUIT

The principles of the Speedomax W bridge circuit have been described in Section L. As stated there, the bridge circuit is arranged so that its ratio arms are always equal.

In the discussion which follows, it is assumed that the bridge circuit is used for temperature measurement with Thermohms—Leeds & Northrup industrial-type resistance thermometers. However, the calculations apply for any type of resistance thermometer.

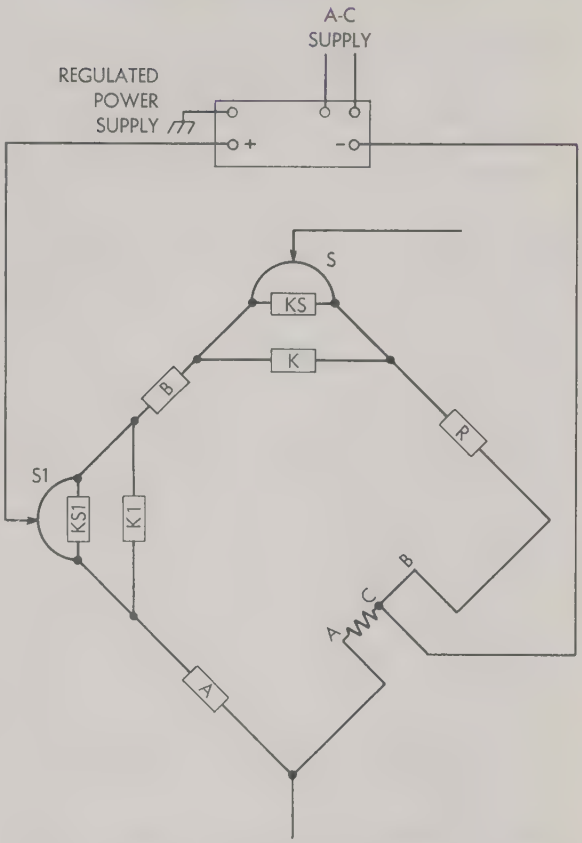


Fig. N5—Diagram for range card calculations for Wheatstone bridge measuring circuit.

Resistance Values—Fig. N5 shows the standard letter symbols used to designate calibrated resistances of the Thermohm bridge circuit. The method of calculating resistances follows:

Resistors KS and KS1—These resistors are mounted on the disks with slidewire S and S1, respectively. All other measuring circuit resistors, marked in Fig. N5, are mounted on the range card.

The values of the various measuring circuit resistors and of the final shunted values of slidewires S and S1 are obtained as outlined below:

Slidewire S—The preshunted resistance of this slidewire is 200 ohms, but it is shunted by resistor K so that the slidewire resistance span is that of the Thermohm being used, over the desired temperature range, plus 2% for overtravel (1% at each end). That is:

$S = 1.02$ Rs ohms

where:

$R_S = R_H - R_L$ in which R_H is the resistance of the Thermohm at the high temperature end of the span and R_L is the resistance of the Thermohm at the low temperature end of the span.

Slidewire S1—The preshunted resistance of this slidewire is 50 ohms, but it is shunted by resistor K1 so that the slidewire resistance span is ½ of slidewire S. Thus:

$$S1 = \frac{S}{2} \text{ ohms.}$$

Resistor K—This resistor shunts the preshunted slidewire S (200 ohms) down to the calculated value of this slidewire. That is:

$$K = \frac{200 \times S}{200 - S} \text{ ohms}$$

where:

S = final shunted value of slidewire S in ohms.

Resistor K1—This resistor shunts the preshunted slidewire S1 (50 ohms) down to the calculated value of this slidewire. That is:

$$K1 = \frac{50 \times S1}{50 - S1} \text{ ohms}$$

where:

S1 = final shunted value of slidewire S1 in ohms.

ResistorB—This resistor is assigned the value of 500.0 ohms.

Resistor A—This resistor is calculated to make the B resistor arm equal to the A resistor arm. Thus:

$A = 500 + S1$ ohms.

Resistor R—The R resistor plus 1% overtravel resistance on slidewire S balance out the resistance of the Thermohm at its low-end value. That is:

$R = R_L - 0.1\ R_S$ ohms.

Section O—TWO-POSITION CONTROL

Two-position control, also called "on-off" or "open-shut" control, is the simplest type of automatic control, and is suitable for many processes where the control requirements are not critical. It gets its name from the fact that the device which regulates the process input, e.g., a fuel valve in the case of a heating process, can assume only two positions regardless of the value of the variable being controlled. In two-position control, the process input is automatically set to one limit when the controlled variable falls below a predetermined level, and is automatically set to the other limit when the controlled variable rises above a predetermined level.

The control switches on the Speedomax W instrument can be used to provide two-position control of the variable being measured. The switches may operate a valve, contactor, damper, or other device controlling the process input.

Depending upon the user's needs, the two- position control may be of either the single point or the differential gap type, as follows:

TWO-POSITION SINGLE POINT CONTROL

In this arrangement, the process input is changed from maximum to minimum and from minimum to maximum at the same value of the controlled variable. Fig. O1 illustrates this control action in the case of a temperature control. Here it is assumed that a single low contact is used to turn on a heating element whenever temperature falls below the set point, and to turn off the element when temperature exceeds the set point.

In any process there is some delay or lag between a change in the input and the resultant change in controlled variable indicated on the measuring instrument. Consequently, as shown in Fig. O1, when heat is turned on, temperature continues to fall for a period before starting to increase. Similarly, when heat goes off, temperature continues to rise for a period before starting to decrease. This alternate overshoot and undershoot of the control point produces the cyclic temperature fluctuation shown. Such cycling is an inherent characteristic of two-position control.

The magnitude of the cyclic temperature swings, and hence the magnitude of the deviations from the set point, is directly related to the heat transfer characteristics and measuring lags of the particular process. Thus if the temperature measurement responds rapidly to changes in heat input, departure from the

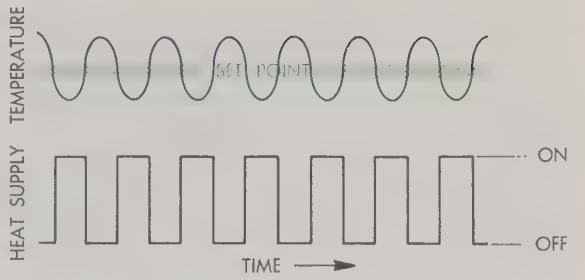


Fig. O1—Two-position single point control action.

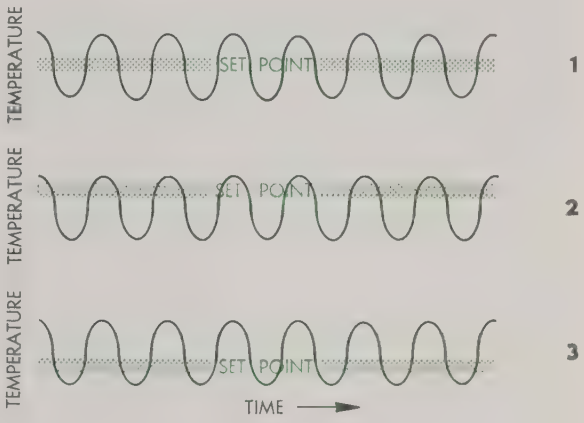


Fig. O2—Effect of process demand on two-position control action.

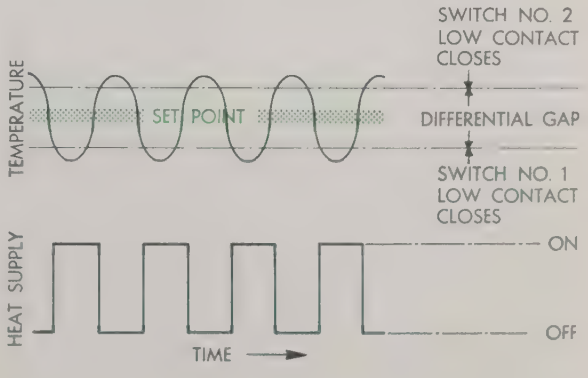


Fig. O3—Two-position differential gap control action.

set point will be small. Conversely, where response is slow, substantial temperature deviations will result. This dependence of the control behavior upon process lags applies not just to heating processes, but to any type of process.

Fig. O2 illustrates the effect of process demand on two-position control. Curve (1) shows the same condition as Fig. O1; that is, temperature cycles evenly about the set point, heater on and off times being equal. For a higher process demand, i. e., more heat required to maintain a given temperature, the response is as shown by curve (2). Here the *on* time is greater, while the temperature cycles at a lower average value than in curve (1). Curve (3) shows these effects reversed for a lower process demand. In general, the ratio of on-time to off-time is proportional to demand, and the control point (or average) is above or below the set point.

TWO-POSITION DIFFERENTIAL-GAP CONTROL

In this method of control, the process input is set to maximum at a lower value of the controlled variable than that at which it is set to minimum. Fig. O4 is a schematic diagram of such a control arrangement. As shown, two control switches are used, but only the low contact of each switch is connected into the circuit. These contacts operate auxiliary relay R which in turn controls the process input.

Control switches No. 1 and No. 2 are set to operate at equal deviations of instrument reading below and above the control pointer respectively. The difference between these two switch settings, measured in terms of scale units, is the differential gap.

Assume that the arrangement shown in Fig. O4 is to be used for controlling an electric heating process. Then the heater contactor coil is connected in series with the SR-2 front contact. When process temperature is below the setting of both control switches, relay SR is energized and the SR-2 front contact is pulled in to turn heat on. At the same time, the SR-1 front contact is also closed. Thus relay SR is kept energized through its own SR-1 front contact and the L contact of control switch No. 2, and heat remains on even after increasing temperature causes the L contact of switch No. 1 to open.

When temperature rises to the setting of switch No. 2, its L contact opens, thereby de-energizing the SR relay coil. This drops out the SR-2 front contact,

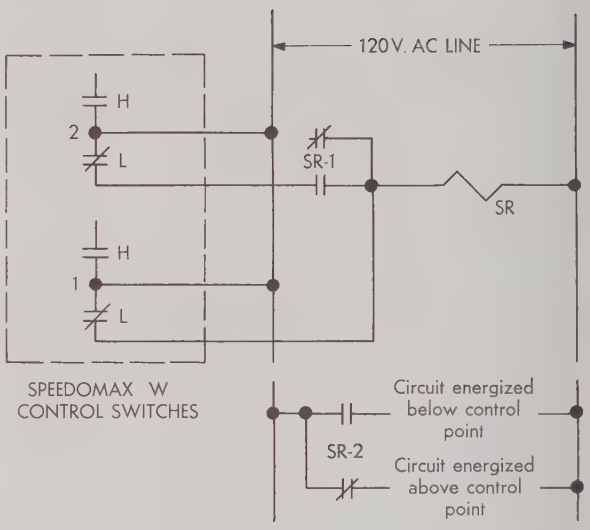


Fig. O4—Schematic of two-position differential gap control circuit using two control switches and an auxiliary relay.

turning heat off, and also opens the SR-1 front contact. The heat then remains off until decreasing temperature again operates control switch No. 1, thus starting a new cycle.

Fig. O3 illustrates the control action provided by this circuit. It can be seen that the response is nearly identical with that of the single point control shown in Fig. O1. Because of the differential gap, it differs in two respects: (1) the magnitude of the cylic temperature swings is greater, and (2) operation of the final control element (the contactor in this instance) is less frequent. In some applications where the final control element is a valve or power contactor, this reduced frequency of operation may be particularly desirable, and usually is the principal reason for using differential-gap control, despite the corresponding increase in deviation from the set point.

In the preceding example, it was required to energize the final control element, i. e., the contactor, for low values of the measured variable. In some arrangements, however, reversed control action might be required, i. e., final control element energized for high-instrument readings. This is done by connecting the final control element in series with the SR-2 back contact, Fig. O4.

PART III—TECHNICAL INFORMATION . . . . .

Section P—MISCELLANEOUS FEATURES . . . . .

THE REGULATED POWER SUPPLY

General Information—The regulated power supply, shown mounted in a recorder in Fig. P1, converts normal a-c line power to d-c power for use in the potentiometer circuit. Its d-c output current will remain at a fixed, constant value despite fluctuations in line voltage between the limits of 107 and 127 volts, variations in frequency from 48 to 64 cycles, and changes in ambient temperature from 16 to 75 C. The magnitude of this d-c current is of critical importance, for in passing through the potentiometer circuit it generates the reference voltage with which all unknown voltages are compared.

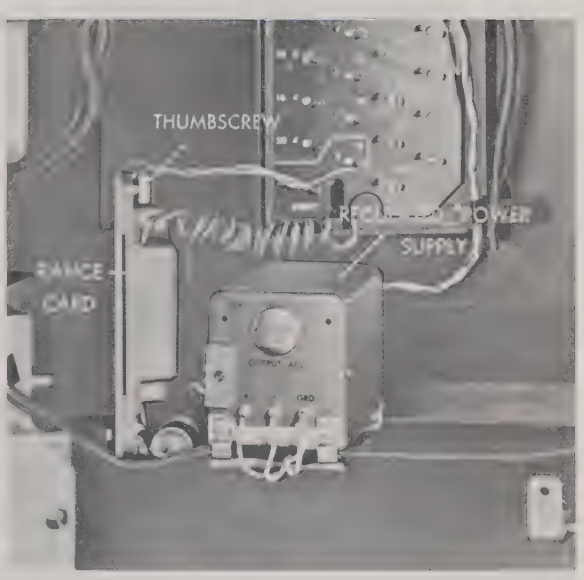


Fig. P1—Regulated power supply mounted in recorder.

Checking and/or Adjusting—There is a particular setting for each 099012 power supply such that it will provide a precise 10 ma d-c current to the potentiometer measuring circuit. A small rheostat, located under the metal cap plug, can be adjusted to furnish the required 10 ma current for circuit resistances between 101 and 109 ohms. Proper adjustment has been made at the factory on each instrument, and the unit should require no immediate attention on the part of the user.

In range card instruments the circuit resistance is determined by the range card and will almost universally be 105 ohms. The interchangeability of range cards is directly dependent upon the known and fixed supply voltage. The power supply therefore should not be adjusted to any other voltage than that for which it was designed. In the case of the range card instrument with a 105-ohm circuit resistance, this voltage is 1.05 volts ±0.05%.

The foregoing does not apply to resistance bridge measuring circuits where the power supply voltage does not directly affect circuit accuracy or range card interchangeability. In this case a different power supply—099018 or equivalent—may be used which will provide a current to the bridge, adjustable between 1 ma and 6 ma. The voltage, however, will depend upon the particular circuit and supply setting, but should normally be between 1.5 and 3.0 volts.

The power supply should be checked and possibly readjusted whenever any field change or inadvertent damage to electrical components has occurred.

When checking the 099012 power supply, use a quality precision potentiometer with a millivoltage output range at least as great as the millivoltage output of the power supply. For the 099018 power supply, use a suitable voltmeter.

Instrument calibration should be made as outlined in Section H *after* the regulated power supply has been checked and/or adjusted.

Theory of Operation—The function of the power supply is to convert normal a-c line power to d-c power having a very stable 10-ma output current. Hence the unit must perform essentially two operations: rectification and voltage-current regulation.

Fig. P2 illustrates the elementary wiring of the 099012 regulated power supply. This unit comprises transformer T1, the printed circuit card, output filter capacitors C3 and C4, and calibrating rheostat R8.

Line voltage is applied directly across the primary winding of T1. The voltage induced in the secondary winding is rectified by a full-wave, bridge-type rectifier consisting of four silicon diodes, filtered by a pi-type R-C network, and regulated by two stages employing Zener diodes.

The first stage of regulation is provided by Zener diode Z1. In previous models two Zener diodes in series were used. The output of this stage is applied to the second stage—a bridge that consists of

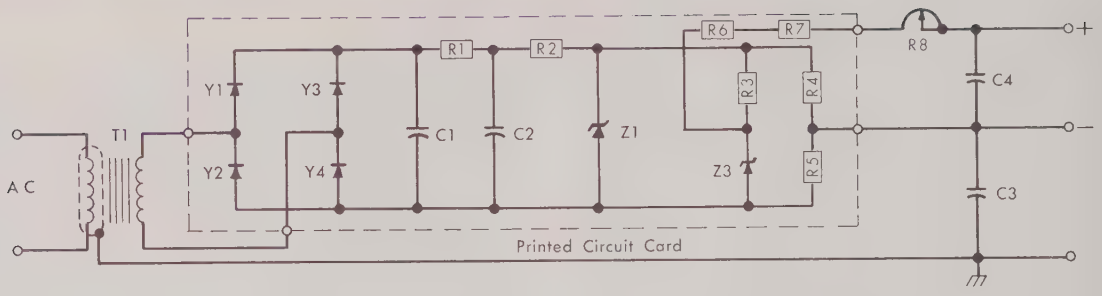


Fig. P2—Schematic of 099012 regulated power supply.

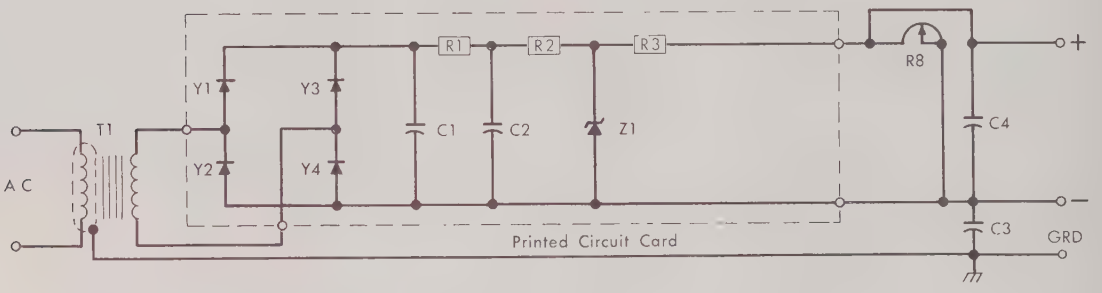


Fig. P2A—Schematic of 099018 regulated power supply.

Zener diode Z3 and three resistance arms. If all four arms of the bridge were purely resistive, a given percentage change in the input voltage across the bridge would cause the output voltage of the bridge to change by the same percentage. But the three resistances—R3, R4, and R5—are so proportioned with respect to the dynamic impedance of Z3 that any change in the input voltage to the bridge will cause the voltage at each output terminal of the bridge to change by equal amounts. Since the bridge output voltage is the difference between the voltages at the output terminals of the bridge, equal voltage changes at these terminals will not cause the output voltage to change. Hence the bridge output voltage remains constant regardless of bridge input voltage changes that are caused by line voltage variations within the limits of 107 and 127 volts a-c.

In a similar manner, the effects of variations in frequency within the limits of 48 and 64 cycles are maintained virtually constant. This occurs because an increase or decrease in frequency produces a corresponding increase or decrease in the rectified bridge output voltage which, like the effects of line voltage variations, is closely regulated.

Since Zener diodes have a positive temperature coefficient of resistance, changes in the ambient temperature will cause the voltage across Zener diode Z3 to change. To compensate for this change, a nickel resistor, which has a negative temperature coefficient of resistance, is wound around Z3 and connected in series with the bridge output. The resistance of the nickel wirewound resistor, R6, is selected so that any changes in the ambient temperature will cause off-setting voltage changes across R6 and Z3. Hence the voltage across the potentiometer circuit is virtually independent of ambient temperature, within the limits of 16 and 75 C.

Fixed resistor R7 of the printed circuit, and rheostat R8, are in series with the potentiometer circuit. R8 is carefully adjusted at the factory so that the current drawn from the power supply is 10.0 ma. Unless the printed circuit assembly or a component on it is replaced, R8 should not require readjustment.

Capacitors C3 and C4, in addition to providing a final stage of filtering, also isolate the output terminals from ground to minimize leakage current effects.

The function of the 099018 power supply is similar to the 099012 described, except that there is no final stage of regulation. See Fig. P2A. This stage is removed because, as pointed out in Section L, bridge currents are not critical and therefore do not require the high degree of regulation that potentiometer currents do.

Maintenance—As has been stated, any future changes to the electrical circuitry of the Speedomax W, such as the installation of new parts or repair work, will necessitate re-executing the adjustment and calibration procedure described above. As a part of this procedure it may be helpful to check the power supply with a voltmeter at its output terminals (marked + and −), but there are no checks to be made on the internal circuitry of the unit itself.

RANGE CARDS

The range card is a printed card assembly, with cover, approximately 2" x 3" x 1", as shown in Fig. P3. It plugs into a receptacle in the instrument case, and is held in place by a thumbscrew. See Fig. P1.

Range cards are available for the two types of standard measuring circuits, namely potentiometer and Wheatstone bridge. Potentiometer circuits include thermocouple and emf. Thermocouple circuits cover most types of thermocouples presently available, while emf circuits cover such primary elements as load cells, pH electrodes, and Rayotubes (radiation detectors). Wheatstone bridge circuits apply to resistance elements such as Thermohm detectors.

The card shown in Fig. P3 is for a thermocouple measuring circuit. Extension leadwires provided with the card vary with the type of thermocouple, and are connected to designated terminals in the measuring instrument.

The circuits on the range cards are generally planned so that the range of the instrument can be changed by removing one range card and inserting another with no further change in the wiring. This procedure applies not only for changing from one range to another with the same type measuring circuit, but also in some cases, to changing from one type of measuring circuit to another so long as the scale and chart paper are also changed. For example, it applies in the case of Rayotubes when the required

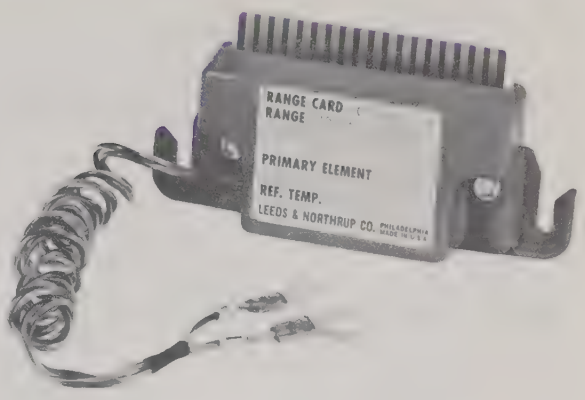


Fig. P3—Range card (for thermocouple measuring circuit).

compensator dial assembly is added to an emf measuring circuit. It applies also to the use of thermocouple or emf cards interchangeably or directly in a Rayotube range card instrument. Finally it applies to changing the range of multiple-point recorders so long as the type of thermocouple is not changed in thermocouple types.

Most cards other than thermocouple, emf, and Rayotube, however, are not interchangeable with each other.

The range of most special range card instruments can be changed in the same manner provided the type of measuring circuit is not changed.

Range cards and the scales with which they are used are available as follows:

CIRCUIT	SCALE
Millivolt	Standard Reversed Standard or from zero center
Rayotube	Standard
Thermocouple	Standard
Resistance (Thermohm)	Standard

(1) Standard Range

This is the form most commonly used. The zero or low limit of the range is at the left end of the scale and the upper limit of the range is at the right end.

(2) Reversed Range

Reversed ranges are opposite standard ranges,

Range Card Type	CONNECTIONS				Fig.
	Fail-safe (Connect one only)		Ref. Junction Comp.		
	Upscale	Downscale	Standard	Remote	
Thermo-couple	• (2 to 3)	o (1 to 3)	Connect where indicated by □ (from b to c)	Connect where indicated by ■ (from a to b & c to d)	P4A
EMF	• (2 to 3)	—	—	—	P4B
Rayotube	• (2 to 3)	—	—	—	P4C

Table P1

i. e., the zero or low limit (most negative) is at the right end of the scale and the upper limit (most positive) is at the left end. See Reversed-Range EMF Range Cards, this section.

(3) Standard Range for Rayotube

Range cards for Rayotube instruments are furnished with the lower limit of the range on the left end of the scale and the upper limit of the range on the right end. In addition, the cards are provided with an integrally mounted double-throw switch. This switch serves to make an instrument more versatile by permitting Rayotubes of different output to be used with the same instrument. For example, in the 1-5 position, the millivoltage compensator range is 1 to 5 millivolts, while in the other position, the millivoltage compensator range is 5 to 25 mv. Thus by merely changing scales and chart paper, a Rayotube instrument can be used with most standard Rayotubes manufactured by L&N.

(4) Standard or from Zero-Center Range

The standard-or-from-zero-center range cards are provided with an integrally mounted double-throw switch marked ZERO LEFT and ZERO CENTER. With the switch in the ZERO LEFT position, the zero is at the left end of the scale. With the switch in the ZERO CENTER position, the zero is at the center of the scale.

There are range cards, however, which call for minor wiring changes, depending upon intended usage. These changes are made either on the card itself or to the recorder input. Cards requiring such changes are:

(1) Reversed-range emf range cards.

(2) Range cards that include input fail-safe and/or reference junction compensation.

Reversed-Range EMF Range Cards—In general, ranges that cause the pointer of an instrument to be driven upscale as the input variable becomes more positive are known as standard ranges. Reversed ranges are just the opposite. They cause the pointer to be driven upscale as the input variable becomes less positive (more negative). Examples of reversed ranges are +10 to 0, −10 to −20, etc.

An instrument furnished with a reversed range has the same measuring and motor circuits as an instrument with a standard range. Therefore standard range cards may be used interchangeably with reversed range cards having the same type measuring circuit. The primary element input connections to the recorder terminal board for reversed ranges, however, are in reverse to those for standard ranges.

For example, to convert a standard range card instrument to a reversed range card instrument, the plus (+) side of the primary element lead must be connected to the minus (−) terminal on the terminal marking strip, and the minus (−) side of the primary element lead to the plus (+) terminal on the terminal marking strip. Conversely, to convert a reversed range card instrument to a standard instrument, the primary element input connections must be reversed so that they match the (+) and (−) designations on the marking strip of the instrument terminal board. Then plug in the required range card. A new scale may be necessary unless the one presently in use can be appropriately re-marked.

Since the measuring circuits are the same for both reversed and standard ranges, reconnections are al-

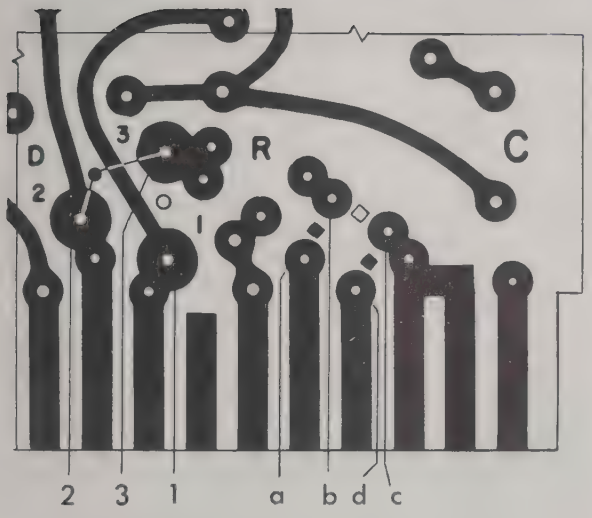


Fig. P4A—Section of thermocouple range card showing connections for input failsafe and reference junction compensation. See Table P1.

ways made with primary element leads only, and not with any leads on the range card side of the terminal board.

Range Cards That Include Input Fail-safe and/or Reference Junction Compensation – The Installation of wiring connections (jumpers) as outlined below may be made by the factory at the time of order processing of the instrument or range card, when specified, or by the user. When not specified the cards are furnished unconnected. Connections are then left to the user. Connections can be made or changed as required in accordance with Table P1 and Figs. P4A, B, and C, depending upon whether the range card contains the necessary components as will be described.

On thermocouple range cards only, the failsafe feature is provided with jacks instead of solder connections. Thus, in making connections or reconnections for this feature, simply insert the wire jumper provided, in the required holes. Make certain that the wire jumper does not come in contact with any circuit foil.

Where connections or reconnections are to be made by soldering, the following items are recommended to avoid damaging the card:

(1) A soldering iron not larger than 25 watts capacity,

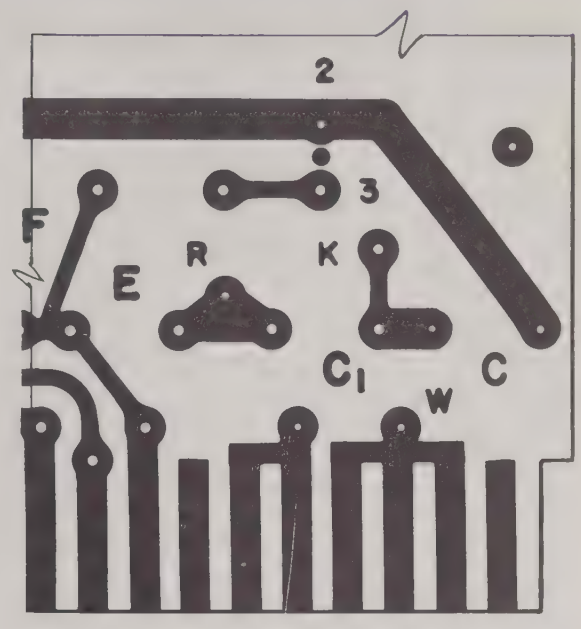


Fig. P4B—Section of emf range card showing connections for input upscale failsafe. See Table P1.

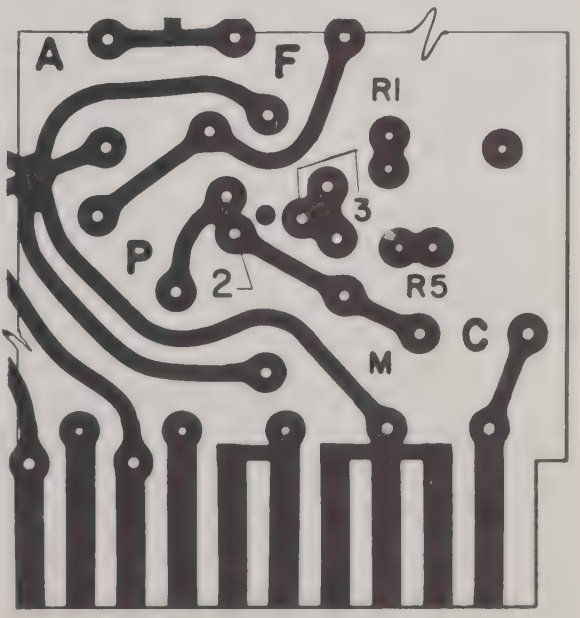


Fig. P4C—Section of Rayotube range card showing connections for input upscale failsafe. See Table P1.

(2) #20 gage or smaller solid, tinned copper wire,

(3) Resin core solder.

(1) Range Card With Failsafe Feature

Failsafe is a safeguard feature which causes the pointer of the instrument to travel upscale or downscale upon failure (opening) of the primary element. The direction of travel is usually effected through appropriate wiring connections on the card itself.

All standard thermocouple, emf, and Rayotube range cards have provision for input failsafe on the printed circuit but only thermocouple and Rayotube range cards are supplied with the input failsafe resistor (R) mounted. Emf range cards are supplied with resistor R only when option 01 and range 0999 are ordered. The reason for not including resistor R for emf range cards is that the source resistance can vary more than in thermocouple and Rayotube applications and therefore the resistor must be individually determined for each case.

On thermocouple range cards, either upscale or downscale failsafe can be provided by installing the jumper in accordance with Table P1. On Rayotube and emf range cards, only upscale failsafe can be provided when the R resistor is mounted and the jumper is installed in accordance with Table P1. On emf range cards, downscale failsafe requires the installation of an input failsafe assembly (L&N Part #164001) without any wiring of jumper(s) on the range card. No provision is available for Rayotube downscale failsafe.

The error caused by the fail-safe feature is negligible provided the external resistance, i. e., the resistance of the thermocouple plus its leads, is small. The error may be of consequence, however, in short range instruments used with thermocouples having long extension wires. Factory calibration of Speedomax W instruments is made on the basis of 40 ohms external resistance. For external resistance other than 40 ohms, error can be calculated by the following equation:

Error (in % of span) =

$$0.1\% + \left(\frac{\text{Source Resistance}}{40} - 1\right) 0.1\%.$$

The error occurs in the direction of fail-safe action.

Speed of response of fail-safe action is usually somewhat slower than the step response of the instrument. For example, for a 5-second instrument it is approximately 5 seconds, and for a 1-second instrument it is approximately 2.5 seconds—for any millivolt span.

(2) Reference Junction Compensation

Reference junction compensation provides correction for any change in thermocouple reference or cold junction temperature. See Section N. This may be effected locally in the recorder or remotely.

Local use is considered standard. In this case, the thermocouple extension leadwires are normally brought directly into the measuring instrument. Connections for local reference junction compensation are listed under Standard in Table P1.

Remote reference junction compensation is generally used where the pairs of thermocouple leadwire from the area of measurment to the measuring instrument would be long and/or many. This feature permits the use of copper wires between these points, and only a single pair of thermocouple leadwires instead of separate pairs of leadwires for each couple. Connections for remote reference junction compensation are listed under Remote in Table P1.

APPENDIX IV

Section Q — FIELD CHANGES AND OPTIONAL FEATURES

RANGE CHANGE

The Speedomax W instrument can be easily converted to a new range of the same type simply by replacing the range card, indicating scale, and chart paper. Refer to Section P.

Remove the old card, together with its leads, where applicable, as instructed in Section F, and install the new card. Replace the scale and check and adjust the alignment as instructed in Section H.

After making the range change, it is advisable to recheck the calibration of the instrument as instructed in Section H.

CHART TEAR-OFF DEVICE

This optional feature facilitates removal of used sections of chart with minimum paper loss. The device consists of a tear-off bar, and a wooden reroll mandrel equipped with tape and clip. Instructions for chart installation and use of the tear-off device are given in Fig. Q1.

FAIL-SAFE AMPLIFIER

As an optional feature, the Speedomax W instrument may be equipped with the No. 101042 Fail-Safe amplifier (refer to part number on side of chassis). This amplifier is designed so that upon loss of signal, due to amplifier failure, the instrument pen and pointer automatically runs to the "safe" limit. Either upscale or downscale operation may be provided, according to the user's requirements.

Under normal operating conditions, the fail-safe feature does not affect instrument performance. However, for reasons described later, the following precaution should be observed.

Important: To assure maximum accuracy, the amplifier gain must be adjusted to the optimum setting as instructed in Section B of this manual.

Fail-Safe Operation — Fail-safe operation may take place in any one of three ways, depending upon where failure occurs in the amplifier circuit. Each mode of operation will be described. In following the explanations, refer to Fig. Q2.

Front End Failure—The grid of the final voltage amplifier stage (pin 7 of V2) is returned to ground through the 12.6 v a-c filament winding. Thus a continuous a-c bias signal is applied to this grid. This bias causes a small shift in balance position but does not otherwise affect instrument performance under normal conditions. However, should the input signal to the final voltage stage be lost due to failure in any preceding stage, the amplified bias voltage causes the motor to run until a scale limit is reached.

Failure of Final Voltage Amplifier—It will be noted that fail-safe operation as just described can occur only if the final voltage amplifier stage is functioning properly. However, if this stage should fail (due to faulty B+ supply or open V2 filament, for example), an a-c bias in the power output stage produces fail-safe action. Under normal conditions, this bias, which is applied through resistor R25 to the grids (pin 7) of tube V3, causes a small shift in balance point but does not otherwise affect instrument performance. Upon loss of V3 grid signal, the bias produces motor rotation.

Failure of Output Stage—The two preceding modes of fail-safe operation can occur only if the power output stage is functioning properly. In case this stage fails (by opening of V3 filament, for instance) fail-safe action is provided by relay Z1, as follows:

The Z1 relay coil is connected in series with the center tap of the V3 plate winding. Under normal conditions, this relay is kept energized by the V3 plate current, and the Z1 back contact is held open, so operation is unaffected. Upon failure of V3 however, relay Z1 drops out and the balancing motor is energized through the Z1 back contact and resistor R26.

Note: While the fail-safe action described in foregoing paragraphs is effective in the great majority of amplifier failures, it does not operate in case of fuse or power transformer failure. However, since the transformer and the large (1¼ ampere) fuse are extremely unlikely to fail, the fail-safe protection is practically complete.

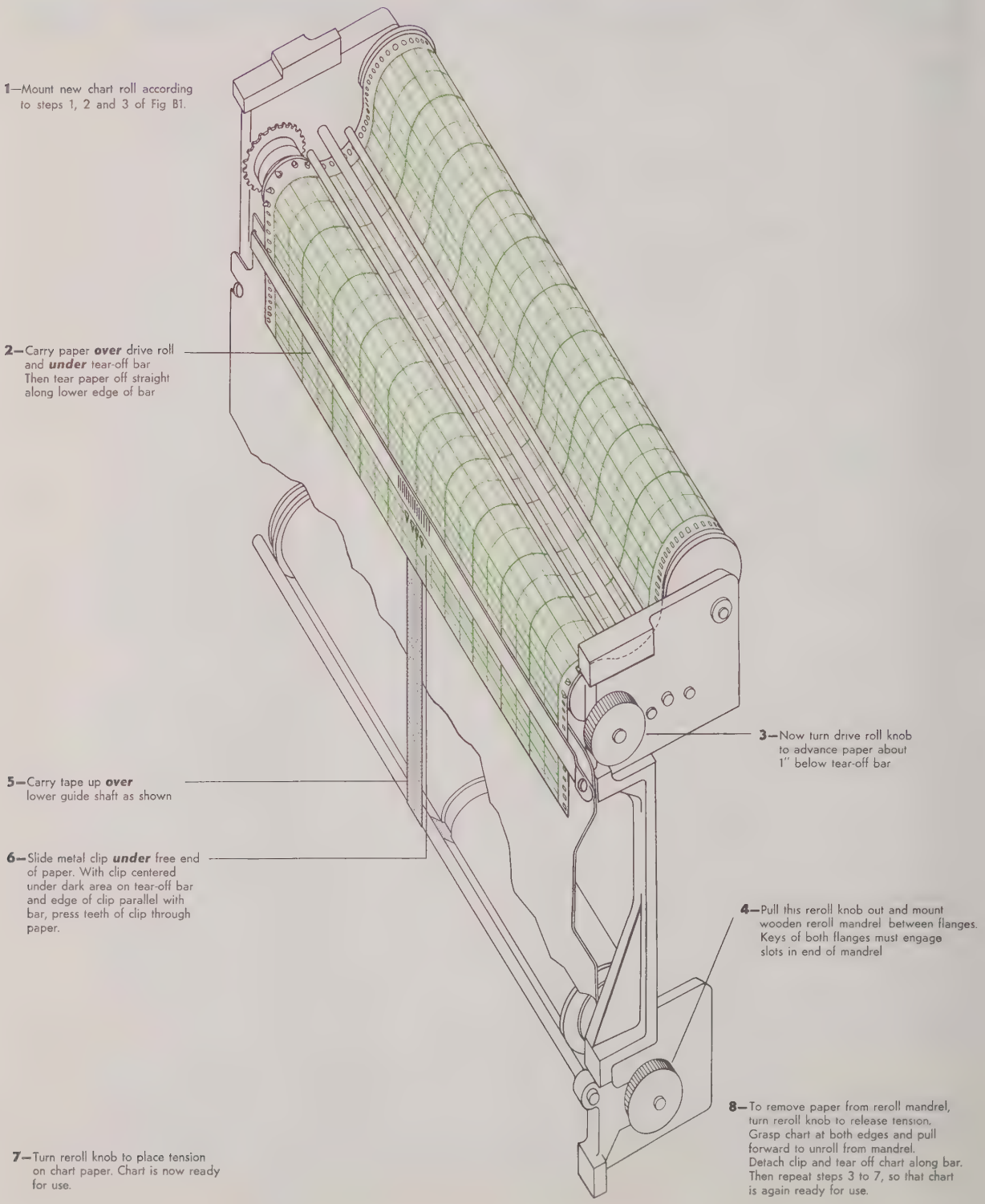

1—Mount new chart roll according to steps 1, 2 and 3 of Fig B1.
2—Carry paper **over** drive roll and **under** tear-off bar Then tear paper off straight along lower edge of bar
3—Now turn drive roll knob to advance paper about 1" below tear-off bar
4—Pull this reroll knob out and mount wooden reroll mandrel between flanges. Keys of both flanges must engage slots in end of mandrel
5—Carry tape up **over** lower guide shaft as shown
6—Slide metal clip **under** free end of paper. With clip centered under dark area on tear-off bar and edge of clip parallel with bar, press teeth of clip through paper.
7—Turn reroll knob to place tension on chart paper. Chart is now ready for use.
8—To remove paper from reroll mandrel, turn reroll knob to release tension. Grasp chart at both edges and pull forward to unroll from mandrel. Detach clip and tear off chart along bar. Then repeat steps 3 to 7, so that chart is again ready for use.

Fig. Q1—Use of chart tear-off device.

Direction of Fail-Safe Action—Normally, the fail-safe amplifier is arranged to produce upscale motor operation in case of amplifier failure. For this arrangement, the amplifier is supplied with adapter plugs. One of these plugs (L&N Part 128079) reverses polarity of the converter drive coil, while the other (L&N Part 040221) reverses phase of the a-c output to the balancing motor. Together these two reversals have no net effect upon normal instrument operation, but the output phase reversal provides upscale travel in the event of amplifier failure. To obtain downscale operation, remove both adapter plugs.

Note: Some measuring circuits are arranged with reverse ranges. In such cases an increase in the input to the amplifier causes the pen and pointer to travel downscale and vice versa. Thus with such a circuit, the terms "upscale" and "downscale" as used in the above description would be reversed. An example of this type circuit is one with a range of 96.5 to 99.7% $H_2 SO_4$, marked on the scale in the usual manner but where the corresponding input varies from 10 to 2.92 mv.

Calibration—As previously stated, the a-c grid voltages employed to produce fail-safe action cause a small amplifier zero offset. Compensation for this offset is made by adjusting the measuring slidewire during factory calibration of the instrument. Since this compensating adjustment is made with optimum amplifier gain, it is important that the gain setting should also be optimum during actual use of the instrument and whenever instrument calibration is checked.

The fail-safe amplifier is freely interchangeable with other amplifiers having the same direction of fail-safe action. Replacement of the amplifier with one lacking the fail-safe feature causes the instrument reading to shift by approximately 0.25% of full scale, while reversal of the fail-safe direction (by removal or installation of adapter plugs) causes a shift of about 0.5% of full scale. Therefore, in the event of such replacement or reversal, instrument calibration should be checked and corrected as instructed in Section H.

Servicing and Troubleshooting — Servicing and troubleshooting procedures for instruments incorporating fail-safe amplifiers are essentially the same as described in Part II of this manual. The few additions and exceptions are as follows:

Check Fail-Safe Action—A rapid check of fail-safe operation can be made by successively removing and replacing the V1, V2, and V3 tubes. Upon removal of each tube, the instrument should run to the safe limit.

Offset Measurement—Measurement of amplifier zero offset is to be made as instructed in Section J, but should be within the limits 5 to 35 microvolts.

Amplifier Troubleshooting – Refer to Figs. Q2 and Q3 when servicing the fail-safe amplifier. Note that some voltage and resistance values differ from those given in Figs. K2, K4 and K6. Table K2, however, is applicable to the fail-safe amplifier.

CHART SPEED CHANGE

Several different chart speeds are available for the Speedomax W. It should be noted that to change from one chart speed to another it is necessary, in some instances, to change both the motor and motor pinion, or the motor or motor pinion only.

The items received from the factory indicate which must be replaced. The procedure for removing and replacing the chart motor and pinion is outlined in Section F, CHART MOTOR. Follow this procedure and replace the necessary parts with the new ones.

OTHER OPTIONAL FEATURES

These features are covered either in separate directions or in drawings supplied with the instrument. Some of the more popular features available, besides those already described, include:

(a) Carrying handle, feet, and line cord
(b) Chart motor switch
(c) Mechanical indexing pen lifter
(d) Off-scale limit features
(e) Writing table
(f) Transistor amplifier
(g) Double chart speeds
(h) Fluorescent illumination
(i) Indexing pen
(j) Rayotube filter circuit
(k) Signal light for power failure

Options (a), (c), (e), (f), (h), (i), and (k) are also supplied in kit form for field mounting on existing instruments. Note however, that because of limited space, not all features desired can be included in a particular instrument. Therefore, before ordering any optional feature, consult the nearest L&N office stating the serial number and catalog number of the instrument for which the feature is to apply.

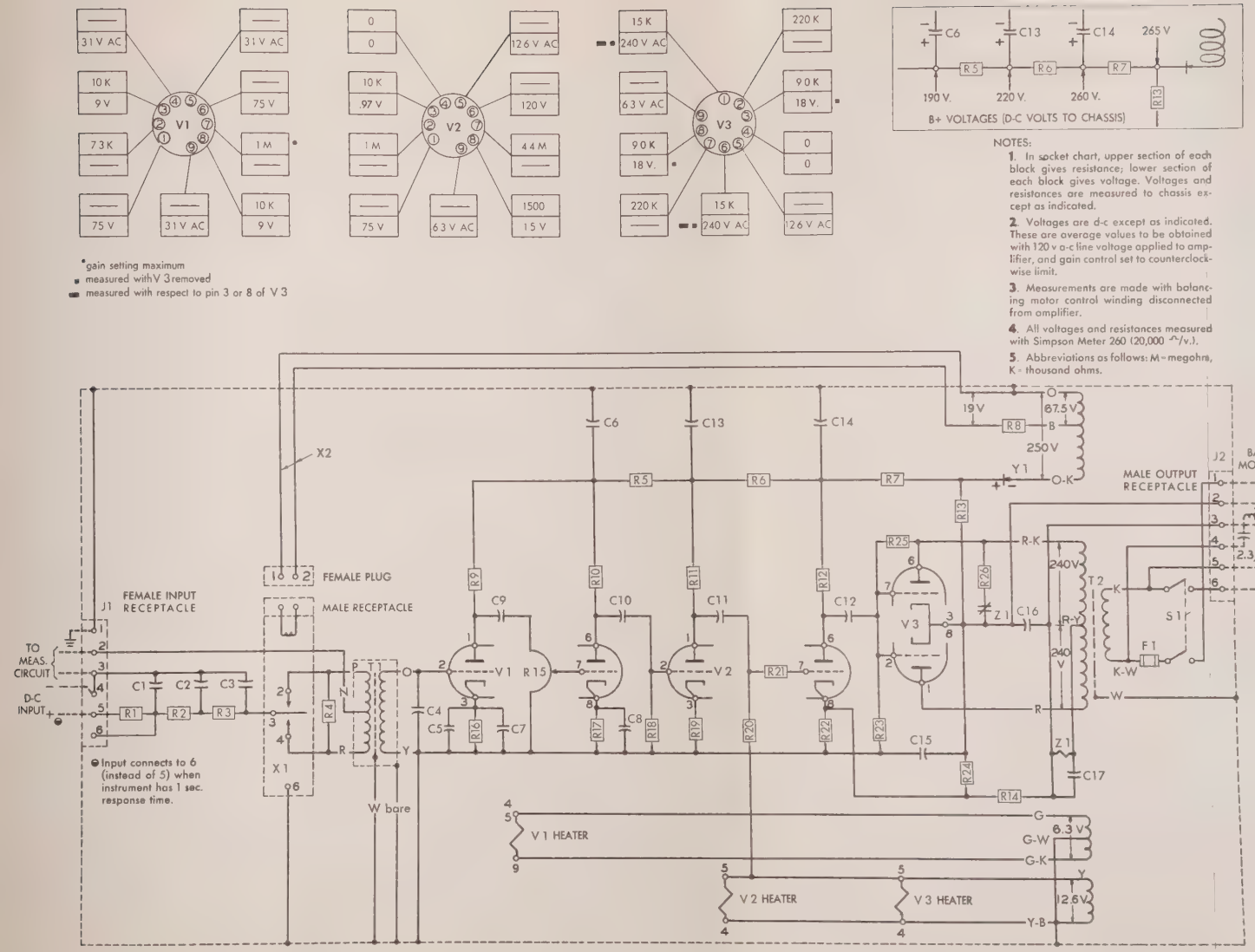


Fig. Q2—Schematic of 101042 or 101043 Failsafe Amplifier with test data.

RESISTORS

			L&N Part No.
R1	5600Ω		11-1-0-53
R2	2000Ω		11-4-0-95
R3	2000Ω		11-4-0-95
R4	10K		11-1-0-56
R5	100K		11-1-0-68
R6	100K		11-1-0-68
R7	10K		11-1-0-56
R8	2700Ω	3W	011623
R9	1 Meg		11-1-0-80
R10	1 Meg		11-1-0-80
R11	1 Meg		11-1-0-80
R12	1 Meg		11-1-0-80
R13	270K		11-1-0-73
R14	22K		11-1-0-60
R15	1 Meg		013138
R16	10K		11-1-0-56
R17	10K		11-1-0-56
R18	1 Meg		11-1-0-80
R19	10K		11-1-0-56
R20	2.2 Meg		11-1-0-84
R21	2.2 Meg		11-1-0-84
R22	1500Ω		11-1-0-46
R23	220K		11-1-0-72
R24	10K		11-1-0-56
R25	6.8M		11-1-0-90
R26	10K	10W	011481

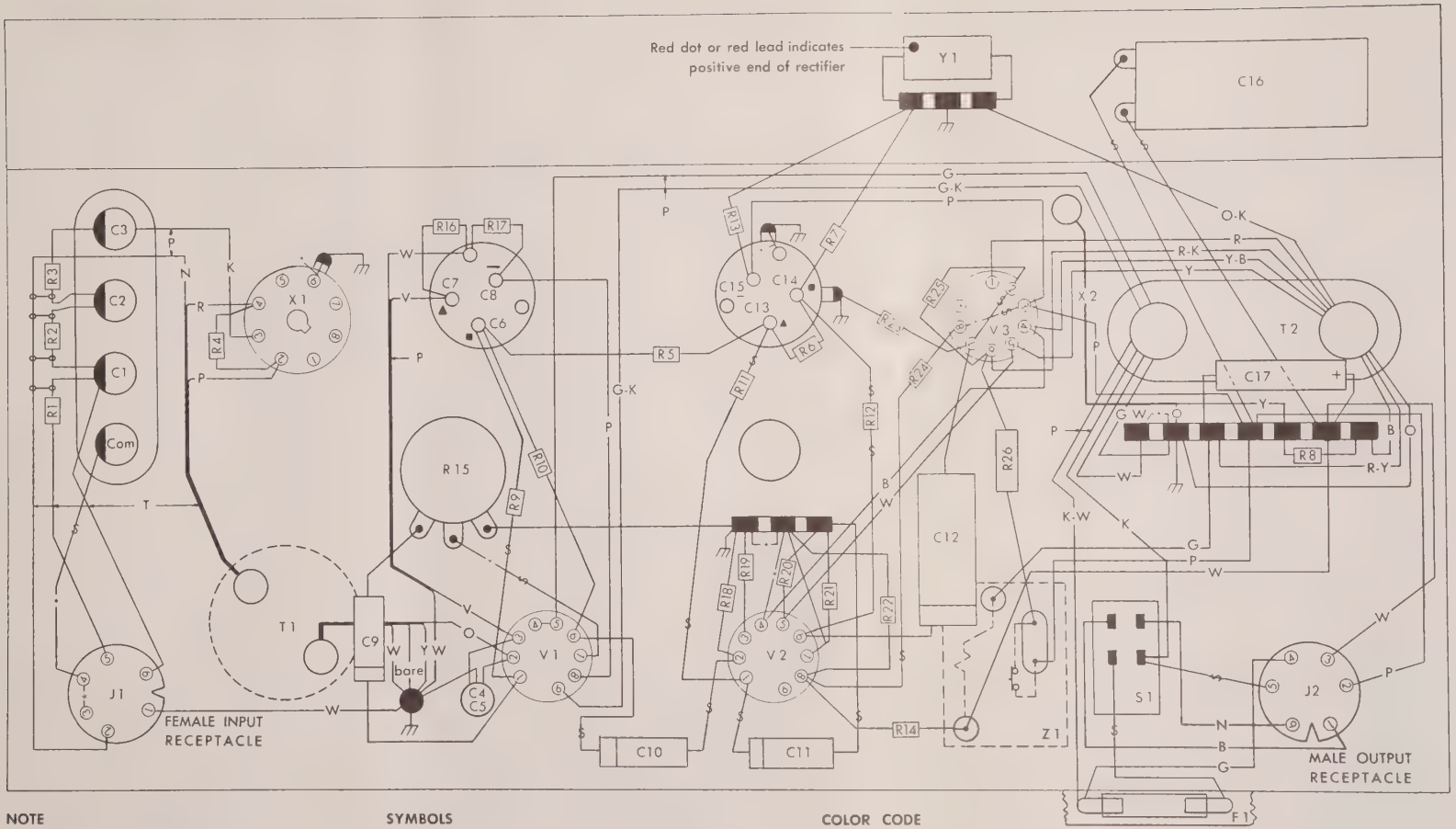
CAPACITORS

C1	8µf	5vDC	R-820-L
C2	8µf	5vDC	
C3	8µf	5vDC	
▲C4	.001µf	500vDC	023125
▲C5	.001µf	500vDC	
▲C6	4µf	300vDC	
▲C7	25µf	2vDC	023123
▲C8	25µf	2vDC	
C9	.022µf	400vDC	23-3-0-20
C10	.022µf	400vDC	23-3-0-20
C11	.022µf	400vDC	23-3-0-20
C12	1µf	400vDC	23 3-0 8
▲C13	4µf	300vDC	
▲C14	4µf	300vDC	023122
▲C15	25µf	10vDC	
C16	1µf	130vAC	023124
C17	50µf	25vDC	Std.-2645-53

MISCELLANEOUS

T1	Input Transformer	Std 21178-39
T2	Power Transformer	019183
▲V1	12AX7	22-1-0-6
▲V2	12AX7	22-1-0-6
▲V3	12BH7	022062
▲X1	Converter 60 cycle	354156**
▲X1	Converter 50 cycle	354169**
X2	Converter Cable	037253
▲F1	1¼ amp Slo-Blo	14-5-0-4
S1	Line Switch	032197
Y1	Rectifier	057016
Z1	Relay	036207
	Socket for V1 & V2	40-1-0-8
	Socket for V3	40-1-0-4
	Output Receptacle	Std. 3246-176
	Input Receptacle	Std. 3246-174

**354156 Converter (60 cycle) used on 101042.
**354169 Converter (50 cycle) used on 101043
▲Recommended for spare parts stock



NOTE

All resistors are ½ watt, with ±10% tolerance except as noted.

SYMBOLS

- indicates leads twisted around resistors
- P — indicates tightly twisted leads
- T — indicates three tightly twisted leads
- S — indicates insulated tubing
- * — indicates tinned wire
- indicates outside foil of paper capacitors

COLOR CODE

K — Black	Y — Yellow
W — White	A — Gray
G — Green	V — Violet
R — Red	P — Pink
B — Blue	S — Slate
N — Brown	T — Tan
O — Orange	

Fig. Q3—Wiring diagram of 101042 or 101043 Failsafe Amplifier.

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